ASTM Bulletin, October, 1947. Published six times a year, January, March, May, August, October, and December, by the American Society for Testing Materials. Publication Office—20th and Northampton Sts., Easton, Pa. Editorial and advertising offices at the headquarters of the Society, 1916 Race St., Philadelphia 3, Pa. Subscription $2.00 a year in United States and possessions, $2.25 in Canada, $2.50 in foreign countries. Single Copies—50 cents. Number 148. Entered as second class matter April 8, 1940, at the post office at Easton, Pa., under the act of March 3, 1879.

ASTM BULLETIN

Published by
AMERICAN SOCIETY for
TESTING MATERIALS

This Issue Contains

NEWS ABOUT THE SOCIETY AND ITS COMMITTEES:

MISCELLANEOUS TECHNICAL NOTES AND NEWS:

OCTOBER—1947

No. 148

ASTM BULLETIN

"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

TELEPHONE—Rittenhouse 6-5315 | R. E. Hess, Editor
R. J. Painter, Associate Editor | CABLE ADDRESS—TESTING

Number 148 | October 1947

New and Revised Specifications Approved by Standards Committee

Actions Involve Non-Ferrous Metals and Alloys, Clay Pipe, Petroleum, Road Materials, Electrical Insulating Materials and Plastics

SEVERAL new tentative specifications and tests were approved by the Administrative Committee on Standards at its meeting in Philadelphia on September 4. At the same time this committee reviewed recommendations from several of the technical committees, with the result that numerous tentative standards have been revised and tentative revisions (published for a year or more for comment) were affirmed.

The accompanying table itemizes the various actions and there is a brief review of the respective technical committee proposals in the material that follows.

All of these new and revised specifications will appear in the 1947 Supplement to the 1946 Book of Standards. These Supplements, to be issued late in 1947 or early in 1948 will be furnished to the members in accordance with the respective parts of the Book which they have received. Because of the somewhat transient nature of the Supplements they are to be bound in a heavy paper cover rather than cloth binding.

Non-Ferrous Metals and Alloys

Two actions approved on the recommendations of Committee B-2 on Non-Ferrous Metals and Alloys involve, first, some changes and the reversion to tentative of the existing standard for Fire-Refined Copper Other Than Lake (B 72). This will now be restricted to cast alloys. The specification B 216 will embody the requirements in the former specification under this designation and the requirements in B 72 thus providing in one document requirements for fire-refined copper for wrought products not intended for electrical purposes.

As a result of discussions in Committee B-7 on Light Metals and Alloys a new alloy GR1 (52S) has been added to the specifications for Aluminum and Aluminum. Alloy Bars, Rods, and Wire (B 211). This material has a range of magnesium

Actions by the A.S.T.M. Administrative Committee on Standards, September 4, 1947

New Tentatives

Specifications for:

Standard-Strength Perforated Clay Pipe (C 211 – 47 T).
Aviation Gasolines (D 910 – 47 T).
Asphalt Cements for Use in Pavement Construction (D 946 – 47 T).
Hot-Mixed, Hot-Laid Asphaltic Concrete Base and Surface Courses (D 947 – 47 T).

Method of:

Test for Knock Characteristics of Motor Fuel by the Research Method (D 908 – 47 T).
Test for Knock Characteristics of Aviation Gasoline by the Supercharge Method (D 909 – 47 T).
Test for the Weight Loss of Plastics on Heating (D 948 – 47 T).

Recommended Practice for:

Molding Specimens of Phenolic Materials for Use in Electrical Tests (D 949 – 47 T).

Tentative Revisions of Standards

Methods of:

Test for Distillation of Cut-Back Asphaltic Products (D 402 – 36).
Testing Sheet and Plate Materials Used in Electrical Insulation (D 229 – 46).
Measuring Dimensions of Rigid Tubes Used in Electrical Insulation (D 668 – 44).

Revision of Standard and Reversion to Tentatives

Specifications for:

Fire-Refined Copper Other Than Lake (B 72 – 33), and a change in title to read: "Specifications for Fire-Refined Casting Copper."

Revision of Tentatives

Specifications for:

Fire-Refined Copper for Wrought Alloys (B 216 – 46 T), and a change in title to read: "Tentative Specifications for Fire-Refined Copper for Wrought Products and Alloys."
Aluminum and Aluminum Alloy Bars, Rods and Wire (B 211 – 46 T).
Magnesium Base Alloy Bars, Rods and Shapes (B 107 – 45 T).
Natural Block Mica and Mica Films Suitable for Use in Fixed Mica Dielectric Capacitors (D 748 – 45 T).
Thermosetting Materials (D 709 – 46 T).
Cellulose Acetate Molding Compounds (D 706 – 46 T).
Cellulose Acetate Butyrate Molding Compounds (D 707 – 46 T).

Methods of:

Conditioning Plastics and Electrical Insulating Materials (D 618 – 46 T).
Testing Insulating Oil (D 117 – 46 T).
Testing Varnished Cloths and Varnished Cloth Tapes Used in Electrical Insulation (D 295 – 46 T).
Measuring Dimensions of Rigid Rods Used in Electrical Insulation (D 741 – 43 T).
Testing Varnished Glass Fabrics and Varnished Glass Fabric Tapes Used in Electrical Insulation (D 902 – 46 T).
Test for Power Factor and Dielectric Constant of Electrical Insulating Materials (D 150 – 46 T).

from 2.2 to 2.8 per cent with copper, manganese, and zinc each at 0.10 per cent maximum, chromium has a range of 0.15 to 0.35 per cent, with aluminum, remainder. This alloy has a range of tensile strength from 32,000 to 39,000 psi. depending on the temper. The changes in the requirements for Magnesium-Base Alloy Bars, Rods, and Shapes (B 107) extend the size range, modify properties somewhat, and include changed tolerances to bring them in line with latest commercial practice.

Perforated Clay Pipe

The new specifications for Standard Strength Perforated Clay Pipe for Use in Drainage (C 211–47 T) are sponsored by Committee C-4 on Clay Pipe. This material, which is used in highway, airport, railroad, and similar construction, has not previously been covered in any standard. The requirements cover materials and manufacture, resistance to acids, and physical test requirements including adsorption, test requirements, size, and workmanship. The perforations, which are to be arranged in rows parallel to the pipe axis, are $\frac{1}{4}$ in. in diameter and are to be spaced about three inches center to center in the rows. Requirements on the number of rows range from four to eight depending upon the pipe size.

Petroleum Products and Lubricants

The three proposals from Committee D-2 on Petroleum Products and Lubricants involve new tentatives, one, a specification for aviation gasoline, and the two others are methods for knock characteristics for aviation gasoline by the supercharge method (D 909) and the research method (D 908). The procedure for determining Knock Characteristics of Aviation Gasoline by the Supercharge Method was developed by the Coordinating Research Council, Inc. It has become widely used in commercial testing of aviation gasoline and Committee D-2 accepted the responsibility of standardizing the procedure. The scope reads as follows: This method describes the test for determining the knock-limited power, under supercharge rich-mixture conditions, of fuels for use in spark-ignition aircraft engines. By operational considerations this method is restricted to testing fuels of 85 ASTM Supercharge Octane Number and over.

There has been considerable discussion in Committee D-2 on the procedures for Knock Characteristics for Aviation Gasoline by the Research Method. This was developed by the Coordinating Fuel Research Committee of the Coordinating Research Council, Inc., and is widely used by motor fuel producers, automobile manufacturers, and to some extent consumers. In course of approval of the method it was pointed out that the method has been in use to increasing extent for about eight years, and has been a distinct aid in describing the gasoline.

The new aviation gasoline specification defines aviation gasoline suitable for some, but not all types, of spark-ignition aviation engines. Certain equipment or conditions of use may require fuels having other characteristics. Two grades are covered, 91–98 and 100–130. An extensive table details requirements and lists test methods used for determining various procedures.

Road and Paving Materials

The new specifications for Hot-Mixed, Hot-Laid Asphaltic Concrete Base and Surface Courses (D 497-47 T) by D-4 Committee on Road and Paving Materials define a type of paving material consisting essentially of a hot-mixed, hot-laid combination of coarse aggregate and fine aggregate, with or without mineral filler, uniformly coated and mixed with asphalt cement in a suitable plant. Heretofore, A.S.T.M. has not issued any specifications for bituminous paving materials and the new specifications will provide requirements for materials and for six mixtures ranging in nominal maximum size of aggregate from $\frac{3}{8}$ in. to 2 in., including requirements for production and control.

In explanation of its development of the new specifications for Asphalt Cements for Use in Pavement Construction (D 946–47 T), D-4 pointed out that nine former tentatives for various types of cement had been withdrawn a number of years ago. Although in existence for some years the committee felt they were not satisfactory for adoption. Consequently, they undertook extensive revisions and major differences of opinion have been dissolved. Two types of cements are covered, petroleum asphalt cement and filled or native asphalt cement. Penetration grades range from 40–50 to 200–300. Extensive tables of requirements cover such matters as penetration at 77 F., flash point, ductility, solubility, and percentage of ash.

Electrical Insulating Materials

A number of tentative revisions of standards and revisions of tentatives (effective immediately) in the methods covering electrical insulating materials, in general bring the requirements in line with the latest practices, or involve rearrangement and classification of the requirements. Important methods for measuring ways or twist of sheet and plate (D 229) have been revised and D 228 and D 741 have been improved. The change in the methods for conditioning plastics and electrical insulating materials (D 618) adds two standard test temperatures and describes the procedures to be used.

Plastics

The new test for weight loss of plastics on heating (D 948–47 T) covers a procedure to be used under defined conditions of exposure to heat and air. The test is designed to give a weight loss of moisture, solvents, or other volatile matter. It is also designed to give volatile matter other than moisture if it can be assumed that the moisture regain by the samples on the reconditioning after heating is equal to that lost during heating.

National Bureau of Standards

Many changes have occurred in the setup of the National Bureau of Standards. With so many A.S.T.M. members concerned with the work of the Bureau, an article describing particularly some of the new divisions at the Bureau, together with a list of the divisions and bureaus and their chiefs, seemed appropriate. This begins on page 34.

Several Publications Issued

Technical Symposiums and Special Compilations of Standards Included

Spectroscopic Light Sources
Rubber Testing
Paint and Paint Materials
Synthetic Lubricants
Petroleum Products and Lubricants
Coal and Coke
Electrical Insulating Materials
Textile Materials
Copper and Copper Alloys

SEVERAL of the books included in the very heavy schedule of A.S.T.M. publications for the 1947–1948 period have been completed and work is progressing reasonably satisfactorily on a number of the others. Brief descriptions of some of the books to be soon completed are given below; it will be noted they include the Symposium on Rubber Testing, the Symposium on Synthetic Lubricants, as well as the Symposiums on Spectroscopic Light Sources and on Paint and Paint Materials. The special Compilations of Standards completed or about to be available, several of which include other related information, are those covering Petroleum Products and Lubricants (Committee D-2), Coal and Coke (Committee D-5), Copper Alloys (Committees B-1, B-2, and B-5), Electrical Insulating Materials (Committee D-9), and Textile Materials (Committee D-13).

While it is expected there will be distributed to each member and committee member in the next several weeks a special order blank, many of the members may wish to transmit their orders now rather than wait for the member's blank.

1947 Supplements to Book of Standards

(December-January)

In order to bring up to date the 1946 Book of Standards and to furnish members and the large number of purchasers of these books all new and revised specifications and tests approved in 1947, Supplements will be issued in December–January. There will be a separate Supplement for each of the five Parts of the Book. The Supplements which will range from 300 to 500 pages, will be furnished to the members in accordance with the members instructions at Headquarters.

The Board of Directors has decided that because of the somewhat transitory use of the Supplements, a year or two at most, they will be bound in a heavy paper cover rather than in cloth. Some members, depending upon the amount of use of the Supplements, may wish to procure cloth or board binders for the books. Prices announced later.

Symposium on Spectroscopic Light Sources

(December-January)

Sponsored by A.S.T.M. Committee E-2 on Spectrographic Analysis, this symposium held at two sessions of the 1946 A.S.T.M. Annual Meeting includes, in addition to four formal technical papers, many discussions by leading authorities in the field. The papers are as follows: "The Present Status of Excitation in Spectrographic Analysis" (B. F. Scribner, National Bureau of Standards), "A Study of the Controlled Spectrographic Spark Source" (J. H. Enns and R. A. Wolfe, University of Michigan), "Some Properties of Gas Discharges Used as Spectral Sources" (R. C. Mason, Westinghouse Research Laboratories), "Short Period Behavior of Spectroscopic Light Sources" (G. H. Dieke, The Johns Hopkins University). This publication should be of interest to all those concerned with spectrographic analysis and related analytical methods. Aggregating about 120 pages, copies can be procured by members at a price of $1.50, the list price being $2.

Symposium on Rubber Testing

This 1947 annual meeting symposium includes eight technical papers giving critical discussion of physical and chemical methods of test, some of which came into considerable prominence during war efforts to extend and conserve rubber and rubber substitutes. A list of the papers and authors follows:

The Significance of Voluntary Standards and Their Status in the Rubber Industry—Arthur W. Carpenter, The B. F. Goodrich Co.

Functions of Rubber Reserve, Past, Present and Projected—W. R. Hucks, Office of Rubber Reserve.

Development of Methods of Chemical Analysis of Synthetic Rubber—Willard P. Tyler, The B. F. Goodrich Co., and T. Higuchi, University of Akron.

Developments and Improvements in Methods of Stress-Strain Testing—J. W. Schade, Government Evaluation Laboratory, and F. L. Roth, National Breau of Standards.

Development and Standardization of Tests for Evaluating Processibility—Rolla H. Taylor, National Bureau of Standards, J. H. Fielding, Goodyear Tire and Rubber Co., and M. Mooney, U. S. Rubber Co.

Standardization of Testing and Inspection in Government Rubber Plants—Ludwig Meuser, United States Rubber Co., Robert D. Stiehler, National Bureau of Standards, and R. W. Hackett, Office of Rubber Reserve.

Testing and Grading of Wild and Plantation Rubbers—Norman Bekkedahl, National Bureau of Standards.

The Use of Statistical Methods in Rubber Evaluation—Marion M. Sandomire, Navy Department, Bureau of Ships.

Together with discussion these papers will aggregate about 116 pages. The price to members is $1.50 per copy; list price, $2.

Symposium on Paint and Paint Materials

The purpose of this symposium and its eleven papers and discussions is to present an up-to-date picture of various methods used in evaluating paints, together with discussion on the increasing significance of statistical analysis of paint test data. Sponsored by A.S.T.M. Committee D-1, the symposium was held in sessions of the Spring Meeting in Philadelphia in February, 1947. To give members an idea of the subjects covered, a list of papers is given as follows:

Test Methods and the Paint Industry—John C. Moore, President, Federation of Paint and Varnish Production Clubs

Methods of Evaluation of Industrial Finishes—R. A. Pringle and E. M. Yacko, Bridgeport Works Laboratory, General Electric Co.

Methods of Evaluation of Automotive Finishes—Frederick G. Weed and Newell P. Beckwith, Rinshed-Mason Co.

Methods of Evaluation of Metal Container Finishes—John H. McKenzie, American Can Co.

Methods of Evaluation of Marine Finishes—Allen L. Alexander, Office of Naval Research

Particle Size by Gas Adsorption—E. N. Harvey, Jr., Interchemical Corp., Research Laboratories

Inclined Tube Viscometer—Maynard Euverard, Interchemical Corp.

Stroboscopic Timer for Stormer Viscometer—E. P. Peterson and Joseph Prane, National Lead Co. Research Laboratories

Introduction to Statistics—A. E. R. Westman, Ontario Research Foundation, Vice-Chairman of A.S.T.M. Committee E-11 on Quality Control of Materials

Application of Statistical Methods—E. I. Stearns, Calco Chemical Division, American Cyanamid Co.

Statistical Analysis of Test Data on Accelerated Weathering of Paints—Roy

Hill, and George S. Cook, Engineer Board, Fort Belvoir, Va., and William E. Moyer, National Lead Co. Research Laboratories.

This publication will comprise some 124 pages, and is available to members at the price of $1.50 paper cover, $2.15, cloth; list prices being $2, paper, $2.65 cloth.

Symposium on Synthetic Lubricants

This symposium, held under the sponsorship of Committee D-2 on Petroleum Products and Lubricants at the 1947 Annual Meeting, comprises three technical papers and discussion, the papers and authors being as follows: "'Ucon' Synthetic Lubricants and Hydraulic Fluids" (J. M. Russ, Jr., Carbide and Carbon Chemicals Corp.), "Synthetic Lubricants from Diesters" (F. J. Glavis and H. R. Stringer, Rohm & Haas Co.), and "Synthetic Lubricants for Military Aircraft" (C. C. Singleterry, Bureau of Aeronautics, U. S. Navy Department). This publication will comprise about 50 pages and can be procured by members at 75 cents, the list price being $1.00.

Industrial Radiographic Standards for Steel Castings

On the recommendations of Committee E-7 on Radiographic Testing, A.S.T.M. has published two sets of standards which were originally developed by the United States Navy, covering Industrial Radiographic Standards for Steel Castings. Issued under the designation E 71–47 T, there are radiographic negatives comprising X-Ray and Gamma-Ray standards. Each set has 31 plates, 5 by 7 in. in size and they are furnished in 9¾-by 8-in. ring binders. Each set is priced at $30 each or both sets (X-Ray and Gamma-Ray) at $55.

These reference standards are intended to assist in classifying defects which may be revealed in castings that have been subject to radiographic inspection. The negatives cover defects which are occasionally encountered and are divided into groups according to the type of defect. An extensive table is used to determine the reference standard which shows the maximum acceptable amount of any type of defect. Suggestions for classifying castings to be used with the standards are given in the printed Tentative Procedure E 71–47 T. This printed procedure, giving a description of the Radiographic Standards, is available without charge from A.S.T.M. Headquarters, but, of course, it is of little service without the Radiographic Negatives.

Entrained Air in Concrete

The eight technical papers with discussion and an introduction, comprising this Symposium on Measurement of Entrained Air in Concrete, were presented at the 1947 Annual Meeting. Probably no subject has occasioned so much interest and intensive discussion, and research and testing, in the past two or three years in the construction field, particularly in highway and related work, as air-entraining cements. A.S.T.M. Committee C-1 on Cement has been much interested in the subject, and the final product in which cement finds its major use, namely concrete, has been the subject of many papers and reports. Various methods for measuring the amount of entrained air in concrete have been proposed and it was the purpose of this symposium to "air" fully these methods and provide critical discussion of them and to provide some evaluation of the procedures. Leading authorities in the field participated in the symposium which was sponsored by Committee C-9 on Concrete and Concrete Aggregates through a special committee headed by A. T. Goldbeck. Covering about 96 pages the symposium in heavy paper cover can be procured by members at the price of $1.30, the list price being $1.75.

Marburg Lecture—Engineering Laminates

The 1947 Edgar Marburg Lecture by Prof. Walter C. Voss, of Massachusetts Institute of Technology, is expected to be available sometime in October–November. This Lecture on the subject "Engineering Laminates—Fundamentals Underlying the Problems of Their Inhomogeneity" will be of interest to all those concerned with the use of composites and laminates, perhaps in particular those men who are involved with problems in the field of plastics, adhesives, and related materials. The Lecture provides a very fundamental discussion of basic concepts of the structure of materials which affect their use as laminates, and this early part of the Lecture is then followed by specific references to various problems. The importance of further research is stressed.

This Lecture is being issued in advance of its publication in the *Proceedings*, in the form of a special reprint which will aggregate about 42 pages, in heavy paper cover. The price to members for the Lecture in this pamphlet form is 75 cents, the list price being $1.

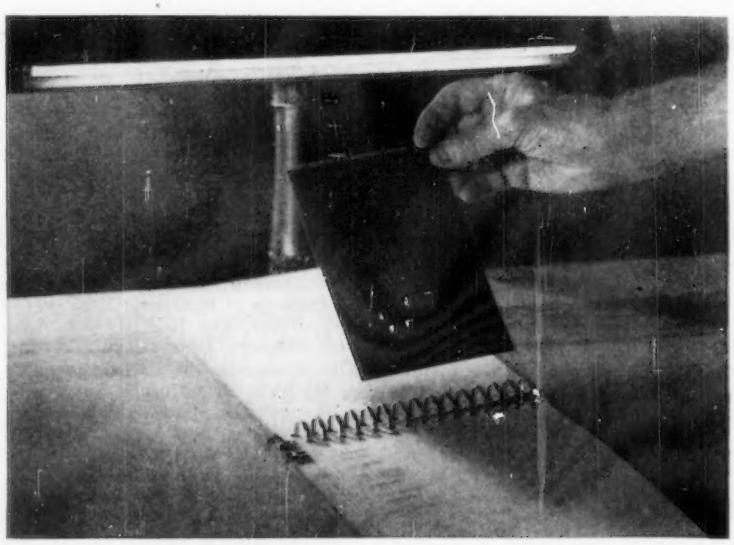
Compilations of Standards

Copper and Copper Alloys—

Copper and copper alloys are marketed in a wide variety of products and forms, and the specifications and tests included in this compilation are indicative of the widespread usage of the materials. There are requirements on wire, cable, plate, sheet, strip, rods, bars, shapes, pipe, tubes, sand castings, etc. This publication has grown in extent, now involving about 480 pages, and it is available to members in heavy paper cover at $3, the cloth binding being $3.65. List prices to nonmembers are respectively, $4 and $4.65.

Petroleum Products and Lubricants—

This compilation is noteworthy from at least two viewpoints—it is the most widely distributed compilation published by the Society, with more copies printed than for any other selection of standards; and it has had a rather phenomenal growth, this



Method for Viewing Standard Radiographic Negatives Without Removing from Binder

year increasing in size to about 710 pages as compared with the 630 in the 1946 edition. With the exception of five methods on octane testing of motor fuels to be issued in a special compilation, it has all the A.S.T.M. specifications and tests pertaining to the field covered, there being upwards of 130 standards and tentatives included. The current edition is available to members at $3.50 per copy in paper binding, and $4.15 in cloth binding; the respective list prices being $4.75 and $5.40. Reduced prices in quantity are in effect for this compilation and in fact on all the A.S.T.M. publications.

Coal and Coke—

In addition to all of the A.S.T.M. specifications and tests on coal and coke, this revised compilation, just available, includes eight proposed test methods which have been drafted in Committee D-5 and are published as information for comment. Since the previous edition carried a 1944 date and even this has not been available for many months a new edition has been eagerly awaited. The members' price is $1.50; list price $2; total pages, 160.

Electrical Insulating Materials—

This compilation, normally on an annual basis, has not been issued for two years and, while it has not increased greatly in size, it is somewhat larger and there have been a number of changes in and additions to the standards and tentatives. The book, sponsored by Committee D-9, has found increasing application in many branches of the electrical industry. Aggregating about 600 pages, the current edition can be procured by members at $3 per copy, the list price being $4.

Textile Materials—

Last year's edition of the Compilation of Standards on Textile Materials was exhausted rather early and this year a considerably larger quantity is accordingly being printed. This compilation is particularly noteworthy for the rather large amount of related information included, in addition to the specifications, tests and tolerances developed in Committee D-13. It provides a rather complete picture of the results of A.S.T.M. activities in this field and is a compendium that every textile technologist should have readily available. The book will run about 530 pages in size, members' price being $3, the list price $4.

Committees and Companies Aid in Building Fund

FOLLOWING through a request from the Board of Directors, a number of A.S.T.M. technical committees have brought to the attention of their members, the aim of augmenting the A.S.T.M. Building Fund so that the Headquarters Building can be owned free of encumbrance as soon as possible. When the decision was reached for the Society to procure its own headquarters building, several of the technical committees voiced some interest in contributing, and following through along these lines the Board contacted the committees in June asking them to consider contacting their members for contributions to the Fund.

It was pointed out that there are quite a number of companies and individuals active in committee work who had not participated in the Fund and who might be willing to do so, and there would be some also who would be willing to make a further contribution.

The following technical committees have taken steps to bring the Building Fund to the attention of their members. To date upwards of $3000 has been received from the various committees.

A-3 on Cast Iron
A-5 on Corrosion of Iron and Steel
B-1 on Wires for Electrical Conductors
B-6 on Die-Cast Metals and Alloys
B-8 on Electrodeposited Metallic Coatings
C-1 on Cement
C-8 on Refractories
C-9 on Concrete and Concrete Aggregates
C-14 on Glass and Glass Products
C-16 on Thermal Insulating Materials
D-3 on Gaseous Fuels
D-5 on Coal and Coke
D-7 on Wood
D-11 on Rubber and Rubber-Like Material
D-14 on Adhesives
D-19 on Water for Industrial Uses
D-20 on Plastics
E-3 on Chemical Analysis of Metals
E-5 on Fire Tests of Materials and Construction
E-6 on Methods of Testing Building Construction

Certain organizations have made substantial contributions to the Building Fund either earmarked for technical committee credits or directly to A.S.T.M. as a result of earlier invitations. A list of these organizations follows:

Republic Steel Corp.
Sorbo-Mat Process Engineers
Underwriters Laboratories, Inc.
James G. Biddle Co.
Apex Smelting Co.
Bessemer Limestone & Cement Co.
Chas. Pfizer & Co., Inc.

Building Fund Summary

To date the members and friends of the Society, both company and individual, have contributed close to $160,000. Actually the total building cost will aggregate about $185,000 and it is hoped that within the next year and a half or two a very considerable portion of the remaining amount can be realized and the building be free of debt.

The March issue of the BULLETIN carried a detailed account of the Building Dedication during 1947 Committee Week and Spring Meeting. In this issue was also given a list of Building Fund contributors up to that date.

The consensus of the reactions of those members and others who have visited and inspected the Building, indicates that it is splendidly located on Philadelphia's Parkway, that the building is well laid out for efficient operations and handling of the numerous staff activities, the committee and administrative meetings, and that the whole structure is in keeping with the Society's standing as a leading technical group.

An Important Announcement on the Advance Printing of Technical Papers Appears on the Next Page.

Advance Printing of Technical Papers

Papers to Be Made Available Prior to Proceedings

In order to make available with discussion many of the technical papers presented at the Annual Meeting but which could not be prepared in advance of the meeting, decision has been reached to strike off copies of these papers as soon as they can be made ready, in advance of inclusion in the A.S.T.M. annual *Proceedings*. There are always a number of papers presented at the annual meeting which normally would not be distributed until the *Proceedings* were completed. In recent years there has been considerable delay each year in issuing this large volume because of various factors, in particular printing delays, but also occasioned to some extent by editorial problems at Headquarters, and in no small measure due to tardiness in the receipt of manuscripts.

After careful consideration a plan is to be tried which will make some papers available months ahead of the normal schedule. Those selected for this first trial are listed here.

ADVANCE PRINTING OF PROCEEDING PAPERS

1. Fatigue Characteristics of Some Copper Alloys, by H. L. Burghoff and A. I. Blank, Chase Brass and Copper Co., Inc.
2. The Creep Characteristics of Copper and Some Copper Alloys at 300, 400, and 500 F, by H. L. Burghoff and A. I. Blank, Chase Brass and Copper Co., Inc.
3. A Study of the Transition from Shear to Cleavage Fracture in Mild Steel, by H. E. Davis, E. R. Parker, and Alexander Boodberg, University of California.
4. Fatigue Characteristics of Rotating Beam *versus* Rectangular Cantilever Specimens of Steel and Aluminum Alloys, by F. B. Fuller and T. T. Oberg, Air Material Command, Wright Field.
5. Some of the Effects of Cadmium, Zinc, and Tin Plating on Springs, by John R. Gustafson, Ford Motor Co.
6. The Chemical Reactions of Aggregates in Concrete, by W. C. Hanna, California Portland Cement Co.
7. The Use of the Maximum Principal Stress Ratio as the Failure Criterion in Evaluating Triaxial Shear Tests on Earth Materials, by W. G. Holtz, United States Bureau of Reclamation.
8. Polarographic Determination of Tetraethyl Lead in Gasoline, by Richard Borup and Harry Levin, The Texas Company.
9. The High-Temperature Fatigue Strength of Several Gas Turbine Alloys, by N. L. Mochel and P. R. Toolin, Westinghouse Electric Corp.
10. Tests for Thermal Diffusivity of Granular Materials, by William L. Shannon and Winthrop A. Wells, Harvard University.
11. The Effect of Blends of Natural and Portland Cement on Properties of Concrete, by A. G. Timms, W. E. Grieb, and George Werner, Public Roads Administration.
12. Physical Characteristics of Steel for Tubular Products, by A. B. Wilder, National Tube Co.
13. Methods for the Determination of Soft Pieces in Aggregates, by D. O. Woolf, Public Roads Administration.

Use This (or Facsimile Blank) to Order Papers

Quantity	Item		Price	Total
——	1.	Burghoff and Blank (Fatigue)	0.35	$——
——	2.	Burghoff and Blank (Creep)	0.35	——
——	3.	Davis, Parker and Boodberg	0.25	——
——	4.	Fuller and Oberg	0.25	——
——	5.	Gustafson	0.35	——
——	6.	Hanna	0.35	——
——	7.	Holtz	0.25	——
——	8.	Borup and Levin	0.25	——
——	9.	Mochel and Toolin	0.35	——
——	10.	Shannon and Wells	0.25	——
——	11.	Timms, Grieb and Werner	0.35	——
——	12.	Wilder	0.25	——
——	13.	Woolf	0.35	——
			Grand Total	$——

Remittance requested with order.
Papers will be mailed when available; *probably* November–December.

Name ——————————
(Please print)

Company ——————————

Address ——————————

The nominal charges for the papers as noted in the accompanying coupon have been fixed largely on the basis of costs incurred. They will be available, it is hoped, sometime in November, but members can send in their orders at any time.

Certain symposiums held at the Annual Meeting are being published soon—see article in this BULLETIN on other publications.

Synopses of many of these papers appeared in the May BULLETIN, Provisional Program

1948 National Meetings

Annual Meeting in Detroit, June 21-25 (with Apparatus and Photographic Exhibits); Spring Committee Week, Washington, March 1.

As previously announced, the Society's 1948 Annual Meeting will be held in Detroit during the week beginning June 21. At this same time in the Book-Cadillac Hotel, which is the headquarters hotel and where the registration will be, the Eighth Exhibit of Testing Apparatus and Related Equipment and the Photographic Exhibit and Competition will be in progress.

The 1948 Committee Week, during which a large number of the Society's technical committees are to convene, is to be in Washington throughout the week of March 1, the headquarters hotel being the Statler but a number of other outstanding hotels will cooperate closely both in respect to sleeping room requirements and meeting rooms. Further announcement will be made concerning the projected Spring Meeting to be held during Committee Week. Some further information on these meetings appears below.

1949 Meetings:

While the exact week for the 1949 Annual Meeting in Atlantic City has to be decided, it will be either the week of June 20 or June 27. The Committee Week and Spring Meeting for 1949 will be held during the last week of February at the Edgewater Beach Hotel in Chicago. Further details of these two meetings will be announced.

1948 Annual Meeting and Exhibits

The 1935 Annual Meeting held in Detroit, at which time there was an exhibit of testing apparatus and related equipment, was one of the most successful held by the Society. Much of the credit for the interest at the meeting went to the Detroit Committee on Arrangements and consequently it is of interest to note that the 1948 Local Committee on Arrangements is already being established by the Detroit District Council. The Council has asked C. H. Fellows, The Detroit Edison Co., to serve as the Meeting Committee Chairman, and he has accepted, thus adding another item to the list of contributions which The Detroit Edison Co. has made to A.S.T.M. activities. Working closely with Van M. Darsey, Detroit Council Chairman, and Secretary Carl Heussner, Mr. Fellows has several subcommittees outlined with chairmen appointed, and appointments of personnel are now being made. A list of the subcommittees and chairmen follows:

Annual Dinner and Ladies' Entertainment, C. E. Heussner, Chrysler Corp.

Apparatus and Photographic Exhibits, J. L. McCloud, Ford Motor Co.

Publicity and Promotion, F. C. Kennedy, United States Rubber Co.

Hotels, F. C. Gambrill, Ethyl Corp.

Finance, B. C. Case, Hanson-Van Winkle-Munning Co.

Plant Visits and Local Transportation Franz Zimmerli, Barnes-Gibson-Raymond Div. Associated Spring Corp.

In order to provide sufficient housing accommodations for members, several Detroit hotels are cooperating, including the Statler, Detroit Leland, the Tullar, Fort Shelby, and others. Through Mr. Gambrill and the Detroit Convention Bureau, members will be advised well in advance on making reservations, etc. One of the factors which will determine where members may wish to stay is the location of technical committee meetings. Since all of these cannot be held at The Book-Cadillac some will be grouped in the cooperating hotels. *Consequently members may wish to stay at hotels where their most important committee meetings will be held.*

There will be only one registration headquarters, namely at The Book-Cadillac.

Leading manufacturers and distributors of testing and scientific apparatus and equipment are being invited to participate in the apparatus exhibit, and all A.S.T.M. members and committee members and those associated with company members will be invited to submit photographs for the photographic competition.

Technical Program:

The A.S.T.M. Committee on Papers and Publications has under consideration quite a number of topics which will be covered in technical papers; some of them perhaps will be the basis of symposiums or special sessions. While it is too early to conjecture what will appear on the final program for the meeting, the following are some of the *suggestions* which are under study and development:

Symposium on Conditioning and Weathering

Symposium or Round-Table Discussion on Methods of Reproducing Large

Downtown Detroit

Numbers of Parts
Creep, Stress Rupture and Short-Time High-Temperature Tension Testing
Round-Table Discussion on Spot Identification Test
Symposium on Mineral Aggregates
Symposium on Gas Turbine Materials
Symposium on Magnetic Testing
Symposium on Latest Methods of X-Ray and Gamma-Ray Inspection

1948 Spring Meeting and Committee Week

Whether or not the Spring Meeting will develop for the Washington Committee Week during the week of March 1 depends upon the status of certain technical subjects that have been proposed, but members will be posted fully, as far in advance as possible. Meanwhile advice of technical committees is being secured as to whether they would wish to meet during the week of March 1, and at the same time arrangements have been set up with several of the leading Washington hotels including the Statler, which is to be the headquarters hotel, to insure that there will be sufficient meeting and sleeping room accommodations.

It is planned to mail to the members sometime in December a hotel return form to enable them to indicate their hotel choice. *They will wish to take some cognizance of the fact that certain groups of committee meetings may be scheduled for specific hotels*, and the information on the reservation form will indicate whether definite allocation of committee meetings has been made to any of the respective hotels.

The new Washington District Council is expected to serve as a nucleus for the Committee on Arrangements in connection with the Spring Meeting and to aid in other ways. (See news article on this new Council elsewhere in this issue.)

Mechanical Vibrations

J. P. DenHartog; Third Edition; McGraw-Hill (New York); 478 pages; $6.

A Timely Book Review

Inasmuch as the DenHartog book was first published in 1934 and is therefore not new (although there have been many important additions), there may be some question as to why the book should be reviewed at this time and in this journal.

This can be answered by stating that it is now, more than ever before, necessary that the materials engineer extend his field of knowledge in order that sounder applications of materials be made in design of modern equipment. The most fruitful branches of extension for the materials engineer appear to this reviewer to be in the fields of (1) experimental stress analysis and (2) vibration. In the latter field, the DenHartog book should be a good "buy" since it combines sound theory with a wealth of practical examples, ranging from hair clippers to helicopters.

In the not-too-distant past, if a part broke in service, the logical answer was to "make it bigger." It is now rather generally known that in the case of many fatigue failures of vibrating parts, this is not a solution; in fact one makes matters worse by adding mass if the system thereby becomes better "tuned," *i.e.*, natural frequency moved closer to forcing frequency.

A proper appreciation of the role of "internal damping" of materials is important. In most cases of vibrating machine parts there is so much external damping that the internal damping is negligible. However, there are exceptions such as certain types of turbine blading and in these cases internal damping is a vital factor. Certainly it is a mistake to use damping factors in evaluating materials, without regard to application. The student of DenHartog's book will see the way in which "damping factor" enters into relations fundamentally and should therefore have a better appreciation of its role in engineering problems.

Certain problems in self-induced vibration are very quickly cured as soon as the phenomenon is recognized as such. A slight change in geometry is often all that is needed. No time should be spent in such cases in trying "stronger" materials.

It has been estimated that over 90 per cent of all service breakages are due to fatigue. Consequently, the materials testing engineer is almost certain to be involved in selection of fatigue testing equipment. A.S.T.M. Committee E-9 on Fatigue is now making a survey of such equipment, and it is quite obvious from the variety of vibratory devices in use that a knowledge of the essentials of vibration theory is a requisite to proper consideration of such testing machines.

Summarizing, the DenHartog book on "Mechanical Vibrations," which might seem offhand to have but little connection with engineering materials, is in this reviewer's opinion a volume which should find its place on the bookshelf of the testing or materials engineer and as he studies the book he will become more competent in his own field.

R. E. Peterson

Ferrous Metallurgical Design

(Design Principles of Fully Hardened Steel)

John H. Hollomon and Leonard D. Jaffe; John Wiley and Sons (New York); 346 pages, 6 by 9 in.; 140 illustrations; $5.

The title of this book is somewhat misleading, even when qualified by the subtitle, "Design Principles of Fully Hardened Steel." Although considerable discussion is devoted to the behavior of steel under stress, the subject matter is directed toward support of a procedure for selecting composition and heat treatment of a steel part for use in engineering structures.

This volume would be of interest if for no other reason than that currently accepted concepts of the physical metallurgy of ferritic steels, plus some new concepts of the authors, are assembled in logical sequence under one cover. It is not recommended reading for the novice, but should be instructive to the advanced student of physical metallurgy so long as he is able to discriminate between concepts based on adequate test data and those based on mathematical formulas derived partly from an assumption. This does not infer that these newer concepts are necessarily wrong, but they would be more convincing if supported by more complete experimental evidence.

The authors' presentation of the hardenability concept is quite clear until they introduce *pearlitic* hardenability and *bainitic* hardenability. Are we eventually to be asked to consider *ferritic* hardenability? Also, much discussion is devoted to characteristics of tempered martensite, leading the reader to believe that such structures are quite common. The fact is that full martensite (or martensite and retained austenite) is seldom attained in the constructional type steels with commercial quenching practice and a fully martensitic structure in the low alloy steels is, with a few rare exceptions, a product of the laboratory.

In the opinion of this reviewer, the discussion on the *Phase Transformation in Steel* was excellently presented, and the section *Mechanical Behavior*, which deals with flow and rupture of steel, was of considerable interest. Also, the authors' treatment of tempering in the section, *Temperability*, is to be commended, even though the uninformed reader might be

misled by the emphasis placed on temper embrittlement.

Certainly the extensive bibliography demands favorable comment, and the only criticism is that in some instances a widely accepted authoritative reference on a particular subject is conspicuously absent. The authors may have purposely omitted such reference to avoid controversy.

Much of the material for this book was selected from reports prepared by the technical staff of the Army Ordnance Department, and from reports of investigations conducted by industrial and university laboratories under contract to the Ordnance Department, or other Government agencies. The authors have done a very creditable job in coordinating the information and in presenting their interpretation of the data.

T. N. ARMSTRONG

Supplement to National Directory of Commodity Specifications

RECENTLY issued through the work of the National Bureau of Standards is a Supplement to the 1945 National Directory of Commodity Specifications. Prepared by Paul A. Cooley, under the direction of G. N. Thompson, Chief of the Division of Codes and Specifications, this 326-page book lists with brief descriptions all new and revised standards and specifications issued through March, 1947. The May, 1945, Directory was issued June 30, 1945. These directories are of great help in locating and comparing commodity specifications. In addition to the data on specifications, both the 1945 book and the current supplement give the names and addresses of the standardizing agencies whose specifications and standards are listed in the books. Most of the A.S.T.M. specifications are covered in the two volumes.

Copies of the Supplement can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at $2.25 a copy, and the 1945 Directory (Publication M 178) is available at $4 a copy.

Principles of Tile Engineering

Handbook of Design

WITHIN the covers of this handbook prepared by Harry C. Plummer and Edwin F. Wanner, Director of Engineering and Research and Research Engineer respectively, Structural Clay Products Institute, have been concentrated the equivalent of a complete engineering course on the subject of structural clay products and their use in construction.

To the beginner, the course opens with an interesting series on the origin and manufacture of structural clay products. Clay brick is known as the oldest of such products; in fact, it is pointed out by the authors that it is the oldest manufactured building material with recorded reference in the Bible dating back to 2247 B.C. Structural clay tile, on the other hand, is of comparatively recent origin—a machine-made product never having been manufactured commercially by hand and first produced about 1875.

With this background established, the authors give a full list of definitions of terms, as included in A.S.T.M. Standard Definitions of Terms Relating to Structural Clay Tile (C 43). Following in succession are sections on classifications of structural clay tile, types of structural wall tile, features of unit design, and shape and size.

Completing the fundamentals included in this course of engineering is found a description of the properties of structural clay tile units augmented by illustrations and tables containing test data reproduced from technical papers on the subject. Numerous reference is made to the various sources of technical information, including reports of A.S.T.M. Committee C-10 (now merged with Committee C-15 on Manufactured Masonry Units) and to A.S.T.M. Standards.

Information on the subject of mortars is given which includes a description of mortar ingredients, noting the specific A.S.T.M. specifications which apply. Mortar properties are described and recommendations made on types of mortar for specific purposes.

The succeeding chapters progress into the main phase of this course of engineering. Properties, design and construction of structural tile walls and partitions; footings, foundations, piers and pilasters; structural clay tile floors and roofs; and fireproofing and furring are taken up in considerable detail. The subject of structural clay tile floors and roofs is probably covered in a more comprehensive manner than any other. A chapter is divided into four parts, each taking up in succession—types, properties of structural clay tile floors, use requirements, and design and construction.

A complete chapter is given over to structural tile masonry details in which typical wall sections and layout details, followed by shape details and typical sections, describe and illustrate, by the use of detailed drawings, the various applications now in use.

To assist the engineer, two appendices are added, one containing design and estimating tables covering weights of various materials used, and one giving a summary of specifications and test methods available, including Federal specifications; Facing Tile Institute specifications, requirements and test methods; and a summary of Proposed American Standard Sizes of Clay Modular Mortar Units. Numerous references are made to A.S.T.M. standards where the quality of materials is involved.

One of the outstanding features of this publication is the quality and number of the illustrations used throughout.

This handbook is available at $4.50 per copy, from the Structural Clay Products Institute, Washington, D. C.

Patents on Powder Metallurgy

AS A result of work at the National Bureau of Standards there has been compiled and published by the U. S. Government Printing Office a comprehensive list of U. S. patents on powder metallurgy. Over 2200 patents are noted with pertinent information for each. This booklet, issued as NBS publication M184, is entitled "U. S. Patents on Powder Metallurgy," by Raymond E. Jager and Rolla E. Pollard, and can be obtained from the Superintendent of Documents, Washington 25, at 30 cents per copy. Remittance should accompany the order.

Directory of Engineering College Research Council and Review of Current Research

THE Engineering College Research Council of the American Society for Engineering Education, with its headquarters at the College of Engineering, State University of Iowa, Iowa City, Iowa, has issued a directory of member institutions. This 116-page book includes a review of current research carried out under the auspices of the various engineering colleges and institutes which make up the council. The publication gives the addresses of the various foundations, stations, and departments, those responsible for the administration of research work, etc. Also listed are research activities, and some idea of the number of personnel and expenditures involved. It is apparent from a brief review of this publication that a great amount of work is under way on a wide variety of problems.

Copies of this publication, heavy paper cover, can be obtained from the Research Council office, John I. Mattill, Secretary, at $1 per copy.

ASTM Bulletin

OCTOBER 1947

NO. 148

NINETEEN-SIXTEEN
RACE STREET
PHILADELPHIA 3, PENNA.

The A.S.T.M. Production Line

THE Society's products—standard specifications and tests for materials, and increased knowledge of the properties of materials—are offered in the tangible form of publications. While several noteworthy 1946–1947 symposiums and special compilations of standards have "rolled off the line," many more are in process of completion. Brief descriptions are given elsewhere in this BULLETIN of symposiums on rubber testing, paint and paint materials, spectroscopic light sources, and synthetic lubricants. Also noted are special compilations of standards in the field of copper and copper alloys, petroleum products and lubricants, coal and coke, electrical insulating materials, and textile materials.

These books find widespread use, the compilations of standards, of course, particularly in the industries covered. They give up-to-date and authoritative information on the materials requirements and tests, and serve a very useful end in promoting the wider use of our committees' products.

The Society (which means the members and the technical committees and the authors) has established an enviable reputation for the quantity and particularly the quality of its publications. Through papers and discussions in committee meetings, at technical sessions of the Society, and at district meetings, A.S.T.M. has achieved widespread recognition through providing forums for the discussion of the properties and tests of engineering materials. It is believed that the numerous publications in the 1947–1948 schedule will still further enhance this recognition.

Advance Printing of Proceedings Papers

ATTENTION is called to an announcement appearing elsewhere in this BULLETIN to make available, at modest cost to those particularly interested, copies of papers other than those preprinted for the Annual Meeting, in advance of their appearance in the annual *Proceedings*. The papers would be complete with discussion in so far as this is feasible. There is always some delay in getting out the complete *Proceedings*, particularly in view of the present congestion at our printer's, and it has been a matter of some concern to us that frequently there have been a number of very excellent papers presented at the Annual Meeting for which no preprints could be made available at the time of the meeting and for which the members would need to wait until the *Proceedings* actually appeared. The present proposal of placing such papers on press as soon as possible will overcome this shortcoming in our publication practice, and we hope will appeal to our members as an additional service. (For details, please turn to page 10.)

Photographs of Society Officers

New Album at Headquarters

THE very desirable practice of having on display photographs of Society officers is being continued at A.S.T.M. Headquarters, but instead of mounting the photographs in frames in the Board Room the photographs of the Incorporators, Presidents and Honorary Members are arranged in a very beautiful, specially bound volume. This valuable book with its complete set of photographs is being maintained in the Members' Lounge and thus is available for examination by the members and visitors at Headquarters. For each individual there is given his official title at the time he was honored by the Society as President or as Honorary Member.

Each photograph is mounted on heavy paper and enclosed in a plastic film. Provision is made for adding Presidents and Honorary Members for some time to come.

Three New Sustaining Members

WE ARE pleased to announce the acquisition by three long-time A.S.T.M. members of Sustaining Memberships. These organizations—Ford Motor Co., Dearborn, Mich.; Cluett, Peabody and Co., Inc., Troy, N. Y.; and the Eastman Kodak Co., Rochester, N. Y.—have been affiliated with A.S.T.M. through other types of memberships for many years, and representatives of the companies have taken part in various A.S.T.M. activities involving technical committee work, District activities and from the administrative end. With these three new Sustaining Members the total number of organizations in this class now reaches 217.

Significant Book Reviews

THIS note has a single purpose—to recommend to members and BULLETIN readers that they read carefully the technical book reviews which are prepared at our request from time to time by prominent A.S.T.M. members who are authorities in the particular fields covered by the respective books. These signed reviews are not only well prepared and interest-

ing but they very frequently discuss problems which are of much significance to those concerned with work on materials.

For example, in this issue R. E. Peterson, Chairman of A.S.T.M. Committee E-9 on Fatigue, has some very pertinent comments in his review of the book, "Mechanical Vibrations" (p. 12); and T. N. Armstrong, active in Committee A-1 on Steel and other groups, records some interesting observations in his review of the book, "Ferrous Metallurgical Design." Metallurgists and designers particularly should note these two articles.

Members who care to develop a few chuckles and perhaps some loud guffaws might note Robert Burns' review of the book "Chemistry of Commercial Plastics," published on page 21 of the August BULLETIN; which review nevertheless presents a significant evaluation of this extensive book.

District Meetings on Petroleum, Silicones, Textiles, and High-Strength Steels

SEVERAL meetings have been scheduled for the fall and winter months by various A.S.T.M Districts, each of these meetings having what promises to be an interesting technical program. A list of the meetings, topics to be covered, and speakers is given in the accompanying table.

All A.S.T.M. members and committee members and friends of the Society are cordially invited to attend these meetings. Invitations are extended in connection with each of the sessions to members of various local sections and councils of other societies whose personnel should be concerned with the topics covered.

Not only will those present hear interesting and instructive addresses, but in the case of the A.S.T.M. personnel, there is the further opportunity of meeting fellow members.

District	*Date and Place*	*Program*
Detroit (Cooperation with Committee D-2 on Petroleum Products and Lubricants)	Wednesday, October 8 (Rackham Building)	PETROLEUM PRODUCTS *C. M. Larson*, Chief Consulting Engineer, Sinclair Refining Co., New York, N. Y. *W. J. Holaday*, Director, Socony-Vacuum Laboratories, New York, N. Y.
Philadelphia (Cooperation with Committee D-13 on Textile Materials)	Thursday, October 16 (Benjamin Franklin Hotel and Edison Building)	TEXTILES SYMPOSIUM ON FLAMMABILITY (afternoon session: 3 speakers) SPECIAL DINNER (6 p.m. *Dr. S. J. Kennedy*, QMC guest speaker) EVENING SESSION (3 speakers)
New York	Thursday, October 30 (Engineering Societies Building)	SILICONES *K. W. Given*, Chemical Dept., General Electric Co., Pittsfield, Mass.
New England	Thursday, October 30 (Providence Engineering Club, Providence, R. I.)	TEXTILE TECHNOLOGY AND MANUFACTURE *E. R. Schwarz*, Massachusetts Institute of Technology, Cambridge, Mass. *E. J. Gibbons*, Eastern Tape and Webbing Co., *F. W. Fraim*, Essex Mills, Inc.
Pittsburgh	Friday, October 31 (Mellon Auditorium)	STEEL High Strength Steels Why, How, Where? *H. Malcolm Priest*, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.
Chicago (With Western Society of Engineers)	Wednesday, November 19 (Engineering Building Auditorium)	RESEARCH *T. A. Boyd*, President, A.S.T.M. *Gustav Egloff*, Universal Oil Products Co.
Philadelphia	Tuesday, December 9) (Franklin Institute)	PETROLEUM—RESEARCH AND ECONOMICS *T. A. Boyd*, President, A.S.T.M. *E. P. Wright*, Atlantic Refining Co.
New York	Thursday, December 11 (Engineering Societies Building)	ELECTRONIC COOKING

November-December District Meetings in Buffalo, Chicago, New York, Philadelphia

FROM the accompanying table it will be noted that District Councils in Buffalo, Chicago, New York, and Philadelphia have meetings planned which should be of great interest to all A.S.T.M. members and others interested in the materials field.

In Chicago the meeting will emphasize the importance of research, with President Boyd giving for the first time his significant paper entitled "Everybody's Doing It Now—Research," and joining him with some specific case histories of the strategic importance of research

will be Dr. Gustav Egloff, Petroleum Technologist, Universal Oil Products Co.

In Philadelphia, President Boyd will speak on December 9 at a meeting covering broadly the economics of petroleum including particularly the supply angle. This is a field in which Mr. Boyd is greatly interested, and joining him in the program is another authority

on the subject, Mr. E. T. Wright, Petroleum Economist, The Atlantic Refining Co. This and the Chicago meeting will to some extent take the form of a President's night.

The New York meeting is of a distinctly different nature, with the demonstration of electronic cooking, and a capacity audience is expected from all fields. The fairer sex is cordially invited.

Buffalo Meeting—An Experiment:

While the Buffalo meeting is somewhat in the nature of an experiment there is no question that it will be an interesting and successful one. For some time those concerned with district meetings and activities have felt it would be of great interest to all A.S.T.M. members and those in the field of materials for leaders in a particular industry to give a "thumbnail" sketch of that industry and its products, and the Western New York-Ontario District decided to ask Messrs. W. H. Lutz, Technical Director, Pratt & Lambert, Inc., and J. Frank Barton, Chief Chemist, The Federal Portland Cement Co., Inc., to discuss their particular fields. Mr. Lutz's talk is entitled "Paint—Servant of Industry" and Mr. Barton will cover "Recent Developments in Portland Cement." Each is expected to provide a background of some of the salient features and statistics of their industries and to bring out among other facts that almost every technical man, and in fact almost everybody, is affected by research and technical developments in these fields.

This Buffalo meeting on November 18 at the Hotel Lafayette is broadly educational in nature and it will typify the type of meeting which it is felt A.S.T.M. Districts should sponsor from time to time.

The technical session of the Buffalo meeting will be preceded by an informal dinner. Reservations can be made through the District Council Secretary, Mr. Joseph Gentile, Pittsburgh Testing Laboratory, 257 Franklin St., Buffalo 2, N. Y.

Schedule of A.S.T.M. Meetings

Date	Group	Place
1947		
Oct. 9, 10	Committee D-14 on Adhesives	Cleveland, Ohio
Oct. 9	Committee D-3 on Gaseous Fuels	Cleveland, Ohio
Oct. 15, 16, 17	Committee D-13 on Textiles	Philadelphia, Pa.
Oct. 16	Philadelphia District (Textiles)	Philadelphia, Pa.
Oct. 17	Committee B-1 on Wires for Electrical Conductors	New York, N. Y.
Oct. 22	Committee E-7 on Radiographic Testing (Executive Council)	Chicago, Ill.
Oct. 22	Committee E-11 on Quality Control of Materials	Philadelphia, Pa.
Oct. 29	Committee E-1 (Technical Committee 10 on Conditioning)	Philadelphia, Pa.
Oct. 30	New England District (Textiles)	Providence, R. I.
Oct. 30	New York District (Silicones)	New York, N. Y.
Oct. 30, 31	Committee D-10 on Shipping Containers	Chicago, Ill.
Oct. 31	Pittsburgh District (High Strength Steel)	Pittsburgh, Pa.
Nov. 3, 4, 5	Committee C-16 on Thermal Insulating Materials	State College, Pa.
Nov. 3, 4, 5, 6	Committees C-1 on Cement, C-7 on Lime, C-9 on Concrete, D-4 on Road Materials	Chicago, Ill.
Nov. 4, 5	Committee D-9 on Electrical Insulating Materials	Atlantic City, N. J.
Nov. 5, 6, 7	Committee B-5 on Copper Alloys	Pittsburgh, Pa.
Nov. 6, 7	Committee D-20 on Plastics	Atlantic City, N. J.
Nov. 10	D-1 on Paint, Varnish, Lacquer, etc. (Advisory Committee)	Atlantic City, N. J.
Nov. 17	Administrative Committee on Papers	Philadelphia, Pa.
Nov. 18	Western N. Y.-Ontario District (Paints; Cement)	Buffalo, N. Y.
Nov. 18	Chicago District (Research)	Chicago, Ill.
Dec. 9	Philadelphia District (Petroleum Economics)	Philadelphia, Pa.
Dec. 11	New York District (Electronic Heating)	New York, N. Y.
1948		
Week of March 1	A.S.T.M. Committee Week	Washington, D. C.
Week of June 21	1948 Annual Meeting and Exhibit of Testing Apparatus	Detroit, Mich.

Washington District Organized

At a meeting at the Cosmos Club, Washington, D. C., on September 18 attended by leading members and officers of the Society, steps were taken to organize a new A.S.T.M. District centered in Washington, D. C. Albert T. Goldbeck had kindly consented to serve as Chairman *pro tem* on appointment by President Boyd and also in attendance at the meeting as councilors *pro tem* were the following: H. F. Clemmer, W. D. Appel, L. W. Ball, T. I. Coe, R. W. Crum, Grant J. Durant, A. L. Feild, A. C. Fieldner, E. L. Hollady, F. H. Jackson, G. E. F. Lundell, W. H. Reynolds, L. J. Trostel, Stanton Walker, B. L. Whittier, and K. D. Williams.

This new district will be called the Washington (D. C.) District, but it is to include a considerable area around the Nation's capital including all of Maryland and Virginia excepting the eastern shore, North Carolina and much of West Virginia excluding the northern and western counties which are included in the Pittsburgh District. There are approximately 500 A.S.T.M. members and committee members in this area, with a large number of them having

residence and offices in Washington, D. C., but there is also a goodly number in Baltimore. Some of the men present were from Baltimore and Richmond and it is expected that these industrial centers will be represented in the Council.

Acting in accordance with the Charter for A.S.T.M. Districts, the meeting requested A.S.T.M. Past-Presidents A. C. Fieldner and G. E. F. Lundell to represent the Council *pro tem* on the nominating committee and to select three other members not on the temporary council. This group will nominate district officers including Chairman, one or more Vice-Chairmen and Secretary, and from 18 to 20 Councilors. Then the Administrative Committee on District Activities will conduct an election among the members and committee members in the district.

It is expected that a meeting of the Council will be held some time this fall to announce a program for the coming year and also to organize whatever activities it may deem desirable from a local standpoint as related to the 1948 Committee Week and Spring Meeting in Washington, beginning the week of March 1.

At the September meeting, Mr. Goldbeck outlined reasons for the organization of a district in this area, noting that an earlier conference had definitely recommended proceeding. Further announcement concerning this district will appear in the BULLETIN and in a communication directed to all A.S.T.M. people in the area involved.

One additional note of interest might be recorded, that the men present at the September meeting represented very wide fields of activity, and that they comprised an interesting galaxy of A.S.T.M. officers and committee officers, and current and past-presidents and national officers of other leading technical and professional societies.

Further Standardization Projects

Notes on Some "D" Committee Work

THIS article notes some of the current standardization activities under way in a number of the "D" committees, these groups being in the nonconstructional materials activity. An extensive article covering a large number of A.S.T.M. committee activities appeared in the August BULLETIN beginning on page 31. Additional notes appearing below are a continuation of this August article. They are based on information received from committee officers and other sources.

PAINT, VARNISH, LACQUER AND RELATED PRODUCTS

Committee D-1 on Paint, Varnish, Lacquer and Related Products has reported on the development of a number of new specifications and methods. The Subcommittee on Drying Oils plans to present proposed methods for heat bodying rate of drying oils, and specifications for dehydrated castor oil.

The Subcommittee on Bituminous Emulsions is completing proposed specifications for asphalt-base emulsions for use as protective coatings for metal, and for coal-tar-base emulsion for use as protective coatings for metal, and also methods of testing bituminous emulsions intended for use as protective coatings for metal.

The group concerned with traffic paint has in preparation a method of test for measurement of the night visibility of traffic paint. This method is based on the use of a portable night visibility meter and may also be adapted to the measurement of night visibility of traffic signs.

The Subcommittee on Volatile Solvents for Organic Protective Coatings is recommending a new specification for heavy mineral spirits and is cooperating with the Philadelphia Paint and Varnish Production Club on a method for determining the solvency of mineral spirits.

Specifications for copper powder for use in anti-fouling paints are to be offered for publication.

The Subcommittee on Cellulosic Coatings has completed the preparation of specifications for raw and cold-pressed castor oil for use in lacquers.

GASEOUS FUELS

Committee D-3 on Gaseous Fuels has in progress an extensive program of development of methods pertaining to the testing of gaseous fuels. Of particular importance to the work is the definition for liquefied petroleum gases which has just been approved by the committee. This definition reads as follows:

> Liquefied petroleum gases—any liquid or liquefiable hydrocarbons which are completely gaseous at 60 F. and 14.7 psi. absolute and whose vapor pressure at 105 F. does not exceed 450 psi. gage. *Note.*—Liquefied petroleum gases usually consist of propane, propylene, butanes (normal butane or iso-butane), or butylenes or mixtures thereof.

A number of proposed methods are at present being reviewed by the D-3 subcommittees and it is expected that they will soon be submitted to the main committee for approval. The Subcommittee on Collection of Gaseous Samples has prepared methods of sampling liquefied petroleum gas and methods for sampling natural gas. The Subcommittee on Measurement of Gaseous Samples has nearly completed work on proposed methods for determination of specific gravity and density of gaseous fuels and they are about to be submitted to letter ballot.

PETROLEUM PRODUCTS AND LUBRICANTS

A very ambitious program of work has been undertaken by Committee D-2 on Petroleum Products and Lubricants. This has required enlarging the personnel and revamping the various subcommittees and technical committees. A four-day meeting was held in Detroit on October 6 to 9, and the next meeting is planned in February, 1948, probably in Washington.

A new Division on Combustion Characteristics has been established and its seven working sections are completing materials for inclusion in a new A.S.T.M. Manual of Engine Test Methods for Rating Fuels. This Manual will include the five knock test methods, namely, Motor, Research, Aviation, Supercharge, and Diesel. Supplementary information to be included covers a statement on the significance of rating fuels, descriptions of reference and standardization fuels, and detailed instructions on apparatus, operation and maintenance, building and utility, and installation. The Manual is expected to be issued in January. Under new work, the Division is studying the Phillips de-

tonation indicator and a redesign of the engine panel board. A jacketed carburetor is being studied and the redesign of the induction system is contemplated.

Through its sections, Technical Committee A on Gasoline is studying various phases of motor gasoline problems. The Section on Gum is engaged in a program of cooperative testing to improve accuracy and determine the significance of Methods of Test for Existent Gum in Gasoline (D 381), Test for Oxidation Stability of Gasoline (D 525), and Test for Oxidation Stability of Aviation Gasoline (D 873). A program is under way to find a means of differentiating between gum and oil in gasoline. The Section on Specifications is attempting to draw up more significant specifications for motor gasoline than the present Tentative Specifications D 439–40 T. The development of a more accurate method for determination of tetraethyllead in gasoline is under way in another section. A new Section VIII on Significance of Tests has been set up to assemble information on the significance of the various tests used on gasoline.

Technical Committee B on Lubricating Oils is studying the viscosity grade classification of both automotive and industrial gear oils.

In Technical Committee C on Turbine Oils, the Section on Oil Systems for Turbines is planning to issue a Recommended Practice for Cleaning Old Turbine Lubricating Systems. The Section on Oxidation has under way a series of cooperative service tests on inhibited oils in marine turbines and plans to gather service data on inhibited oils in as many turbine units as possible. The Section on Emulsion Tests will study the effect of mechanical, air, and steam agitation on emulsion tests, and also the repeatability and reproducibility of the test procedure. The study of various film strength testing machines is being continued. Technical Committee C is planning a symposium on "Service Experience with Inhibited Turbine Oils" in 1948.

Technical Committee E on Burner Fuels is engaged in revision of the Tentative Specifications for Fuel Oils (D 396–39 T).

Technical Committee G on Lubricating Grease is continuing its study of grease analysis methods with special attention to the determination of free fat, and to the analysis of greases containing asphaltic material. Work continues on a method for determination of coexisting free acid and free alkali in greases, and a study is being made of the effect of metals on greases. Improvement in the evaporation cell used in the method for determination of evaporation loss is on the program. The Section on Emulsion Tests is continuing its study of the thixatropic nature of greases with particular attention to rate of shear, temperature, and reversibility on thixatrophy.

Technical Committee H on Light Hydrocarbons is developing an accurate method for vapor pressure determination. The NGAA-CNGA Table of Physical Constants of Light Paraffin Hydrocarbons is being amplified and enlarged. This committee is also continuing its work on bringing the Rubber Reserve methods of test and analysis into A.S.T.M. standardization.

Technical Committee J on Aviation Fuels completed the new A.S.T.M. Specifications for Aviation Gasoline (D 910–47 T), issued by the Society as tentative on September 4, 1947. These specifications cover grades 91–98 and 100–130 of aviation gasoline. Work is now under way on specifications for 115–145 grade aviation gasoline for inclusion in the first revision of Specifications D 910.

Work in progress in the various subcommittees charged with the development of test methods has also been very active and a few of the problems being studied are briefly mentioned.

A modified procedure for the determination of penetration of petrolatum is being studied, as is a method for determination of oil content of microcrystalline wax. A study of viscosity index is under way. Still another group is studying the applicability and relative merits of various lamps and lamp assemblies now in use for sulfur determination.

The Subcommittee on Distillation is attempting to develop a vacuum distillation method. A cooperative test program designed to develop an improved method for acid number is under way in another subcommittee.

Work continues on gaging procedure, calibration of measuring apparatus, temperature measurement, tank calibration, calculations and volume correction and oil measurement tables, and sampling. This activity is expected to result in the preparation of a Manual containing up-to-date information on these subjects.

The Subcommittee on Nomenclature is working on a glossary of terms and symbols for use in spectroscopic methods of analysis.

The analysis of calcium and barium sulfonates and also methods for direct determination of inorganic salts in sulfonates are being investigated by another subcommittee.

The Subcommittee on Analysis of Petroleum Products for Hydrocarbon Types has under way several procedures for determining the following:

1. Total olefins and aromatics in gasoline.
2. Olefinic unsaturation by bromine titration.
3. Olefins in gasoline (nitrogen peroxide method).
4. Small concentrations of aromatics in gasoline, kerosine, and gas oil.
5. Refractive index of petroleum products, and the use of monochromatic light sources for refractometric measurements.
6. Benzene and toluene in light fractions by ultraviolet spectrophotometry.
7. Individual C_4 hydrocarbons in mixtures, by infrared spectrophotometry.
8. Propane, isobutane, and normal butane in saturated mixtures, by infrared spectrophotometry.
9. Other methods under consideration are: (*a*) butadiene by ultraviolet, (*b*) analysis of isooctane N-heptane mixtures by infrared, (*c*) purity of *iso*octane by infrared, (*d*) purity of normal heptane by infrared.
10. Hydrogen content of petroleum products by the lamp method.

COMMITTEE D-17 ON NAVAL STORES

Committee D-17 on Naval Stores has under way cooperative investigative studies of several new methods. A rather extensive collection of descriptions of softening point tests developed by various investigators used principally in the testing of resins and naval stores has been compiled. It is believed that such information will be of assistance to the committee and others interested in this subject and it is proposed to request publication of it by the Society. This committee is cooperating with Committee E-1 on Methods of Testing in an attempt to combine the two ring-and-ball softening point methods, using, respectively, the straight ring (D 36) and the shouldered ring (E 28) in a single method.

Results of cooperative tests on acid number, unsaponifiable matter, ash, and iron in rosin indicate that the procedure for determining ash is satisfactory, but further work is planned on the others.

The Subcommittee on Tall Oils presented data reported by 17 collaborating laboratories for acid number, saponification number, and rosin acid number by electrometric procedures on samples of whole tall oil and refined tall oil. Very excellent agreement was shown by all the laboratories—contrasting with the generally poor values reported last year by visual titrations using colorimetric indicators. The proposed electrometric procedures will be sent to committee letter ballot for approval as tentative as an alternative to the present visual methods.

A cooperative program with Committee D-12 on Soaps and Other Detergents is planned on rosin acids determination using the electrometric titration procedure. The committee is looking forward to adoption of the electrometric method for referee purposes at least, and also the possible elimination of the McNicoll method,

recommending only the modified Wolff method.

Excellent progress has been made so far in the establishment of test methods for pine tar and pine tar oils.

The Subcommittee on Terpene Hydrocarbons and Pine Oil has presented preliminary data on the cooperative samples of dipentene, pine oil, and turpentine. The results reported on dipentene were considered in good agreement, with the exception of the polymerization test. The possibility of improving the latter test was discussed; however, it was concluded that, if the proper strength acid was used and the empirical procedure closely adhered to, satisfactory results could be obtained with the test as now described.

The Dipentene Methods (D 801) are considered satisfactory for adoption as standard, with (*a*) substitution of the proposed distillation test for moisture in the place of the present dilution test, and (*b*) enlarging the description of the regular A.S.T.M. distillation test to include the specific points at which the temperature readings should be recorded.

In view of high total alcohols results reported by one laboratory on pine oil sample by prolonged heating, it is planned to investigate this point further before the Pine Oil Methods (D 802) are adopted as standard.

Development of a distillation procedure for determining moisture in dipentene along with collaborative work on the tentative method for water in liquid naval stores by the Karl Fischer method is under way.

Committee C-8 on Refractories Holds Summer Meeting

Blast Furnace Refractories to Be Studied

THE pleasant environment of Granville Inn, located at Granville, Ohio, the home of Denison University, formed the setting for a very fruitful and well-attended meeting of A.S.T.M. Committee C-8 on Refractories over a two-day period, August 27 and 28.

Two new developments of interest to the refractories field were initiated as a result of action at the main meeting. One was the decision to form a new subcommittee to study the use of carbon as a refractory in blast furnaces. The committee is aware that this field has been growing to the extent that before long, test methods and specifications will be required for that refractory. The other development was the action taken to form a new section under the Subcommittee on Tests to study test methods which would simulate the disintegration that occasionally occurs in fireclay refractories used to line blast furnaces. Various tests are now used to study the disintegration of blast-furnace refractories by carbon monoxide and there is a definite need for a standard procedure.

The highlights of the several subcommittee reports submitted and discussed show healthy progress being made. Research activity has been continuing, especially on the subjects of creep and tensile strength. Useful studies pertaining to the hot load test are being started in the ceramic departments at several universities whereby students will investigate as thesis work the effect of load and endeavor to develop procedures for special refractories.

It is expected that one of the variables in the PCE test affecting reproducibility will be learned in a cooperative study, involving all types of furnaces, through the use of a set of "standard" samples which are to be made into cones by a mechanical means so as to eliminate one source of error. Action was taken to instruct the Subcommittee on Tests to conduct a fact-finding study on a panel test for refractory insulation to evaluate shrinkage at high temperatures. It is expected that a minor change in the procedure for the panel spalling test for fireclay plastic refractories will be presented to the committee shortly. In the difficult field of definitions, two additional terms were adopted pertaining to "magnesite-chrome brick" and "chrome-magnesite brick."

It was reported that final arrangements were being completed for the publication of the new and revised edition of the informative and widely used "Manual on Refractories" which is expected to be available in December–January. Plans were announced to hold the next meeting of the committee during A.S.T.M. Committee Week in Washington during the first week in March, 1948.

Committee E-11 on Quality Control of Materials

COMMITTEE E-11 on Quality Control of Materials was organized in June, 1946, as announced in the August, 1946, ASTM BULLETIN. Since then the Advisory Committee has held seven meetings and has developed a broad program on which work has already been started. The main committee has held two meetings and another will be held at Society Headquarters on October 22, 1947.

The committee was organized to promote the knowledge of quality control methods and their application to A.S.T.M. work. Membership on the committee is held only by individuals and the number at any time is limited to 25, except that additional individuals may be selected to work as Consulting Members on specific Task Groups.

It is the plan of the committee to develop written material suitable for use in the application of statistical methods to the problems of collection, analysis, and presentation of data. Some of this material will be made available as Recommended Practices, some as sections of an "A.S.T.M. Manual on Quality Control of Materials." The present A.S.T.M. Manual on Presentation of Data with its two supplements, A and B, when suitably revised will constitute three sections of this new Manual. Each new section will be undertaken as a project by a Task Group chosen for the purpose. As

each section is completed, it will be made available. As the work progresses and more sections are issued, the collection of sections will be brought together in a suitable form for publication in two or more distinct parts.

The projects to be undertaken appear for present purposes to fall in three general categories:

1. General projects relating to statistical techniques. Such subjects as editorial revisions of the present A.S.T.M. Manual on Presentation of Data and its two supplements, sampling fluctuations of averages, significance tests, and accuracy and precision are under consideration. It is not proposed that texts on statistical methods be written—rather general educational material covering some simpler techniques useful to engineers will be prepared.

2. Plans for determining conformance to specifications. Principles and problems in sampling, sampling plans, and number of tests to make are being considered under this heading.

3. Miscellaneous specific subjects of A.S.T.M. interest. Under this heading such projects as the following are under consideration: Designation of numerical requirements, planning interlaboratory test programs, and the setting of specification limits.

The job outlined for itself by Committee E-11 is a big one and its completion will require considerable time. Several task groups have already been organized and are working actively on their assignments. The task groups are as follows:

TASK GROUP NO. 1 ON EDITORIAL REVISIONS OF THE A.S.T.M. MANUAL ON PRESENTATION OF DATA AND SUPPLEMENT A:

Scope.—To prepare Sections 1 and 2 of A.S.T.M. Manual on Quality Control of Materials, such sections to comprise editorial revisions of (*a*) Main Section of A.S.T.M. Manual on Presentation of Data, and (*b*) Supplement A thereof; content to be substantially unchanged, except that consideration is to be given to the omission of text material on skewness.

TASK GROUP NO. 2 ON EDITORIAL REVISIONS OF SUPPLEMENT B OF A.S.T.M. MANUAL ON PRESENTATION OF DATA:

Scope.—To prepare Section 3 of A.S.T.M. Manual on Quality Control of Materials, such section to comprise editorial revision of Supplement B of A.S.T.M. Manual on Presentation of Data: content substantially unchanged, except for modifications to treat separately charts for number of defects and charts for number of defectives, as covered in "Note Regarding April, 1943, Reprinting," and to include additional examples if needed.

TASK GROUP NO. 3 ON NUMERICAL REQUIREMENTS IN STANDARDS:

Scope.—To prepare a recommended practice based on the subject matter of Sections 3 to 6 of Tentative Recommended Practices for Designation of Numerical Requirements in Standards (A.S.T.M. Designation: E 29–40 T) in a simplified form to be of maximum usefulness to specification-writing committees; and to make recommendations regarding ways and means of making available the remainder of material in E 29 (either present content only or combined with additional material) in a form most useful to A.S.T.M. membership.

TASK GROUP NO. 4 ON SURVEY OF ACCEPTANCE SAMPLING PLANS IN A.S.T.M. SPECIFICATIONS:

Scope.—To make a survey of Sampling Plans used in A.S.T.M. Standards and Tentatives, and in the survey to disclose the variety and types of materials in such manner as to make statistical evaluation of these plans possible.

TASK GROUP NO. 5 ON PLANNING INTERLABORATORY TEST PROGRAMS:

Scope.—To prepare a report of recommendations on planning for the collection of multi-source data intended specifically for aiding committees of the A.S.T.M.; such report to include consideration of such items as statement of the objective, utilization of prior knowledge, selection of testing equipment, number of contributing sources, number of samples from each source, method of selecting samples, forms for collecting data, and methods of statistical analysis; to be prepared in a condensed form suitable for use as a section of the A.S.T.M. Manual on Quality Control of Materials.

TASK GROUP NO. 6 ON SAMPLING FLUCTUATIONS OF AVERAGES:

Scope.—To prepare a brief presentation on the distribution of averages of samples of size n from a known distribution. An application is the determination of size of sample that must be taken for a desired precision of an average. The general approach of the "Proposed Recommended Practice for Calculating Number of Tests to Be Specified in Determining Average Quality of Textile Material," Appendix V, A.S.T.M. Standards on Textile Materials may be used as a guide.

A seventh task group on Precision and Accuracy is now being organized.

Part of the committee's activity has been devoted to answering requests from technical committees of the Society for information concerning the application of quality control methods to problems associated with the preparation of standard specifications and methods of test. The committee is not in a position to undertake the study of specific problems of individual committees but can advise on those of a general nature. It is hoped that as sections of the A.S.T.M. Manual on Quality Control of Materials are completed, they will provide guidance to the various technical committees in their regular work.

Grant's "Statistical Quality Control"

MEMBERS of the Society who are interested in applications of statistical methods to quality control will be interested in a recent book, "Statistical Quality Control," by Professor Eugene L. Grant of Stanford University. Extracts of two reviews of this book published in the March issue of *Industrial Quality Control* are reproduced for the information of A.S.T.M. membership. This material is printed with the kind permission of the Editorial Board of the American Society for Quality Control. Many will wish to read the complete reviews by referring to the March, 1947, issue of *Industrial Quality Control.*

GRANT, EUGENE L., "Statistical Quality Control," McGraw-Hill Book Co., New York and London, 1946, 563 pp., $5.

Review by H. F. Dodge, Bell Telephone Laboratories

This book gives an excellent presentation of those simple but powerful statisti-

cal techniques that can be widely used in industry, more particularly in production and inspection operations, to control the quality of manufactured products, and to reduce costs.

Explaining that the book is a working manual, the author describes the general purpose of the book in the following words:

> "The most effective use of these (statistical) techniques depends upon their being understood by production and inspection supervisors, by engineers, and by management. The object has been to write a book that might be immediately useful to all of these groups. No attempt has been made to write for the professional statistician or the mathematician. The aim has been to give just enough theory to supply practical working rules that will enable one to recognize the limitations of the methods as well as their many uses."

The author has attained this objective, writing with a clarity that should take much of the mystery out of the specialized language of the statistician. . . .

Profiting from the trend of things during the war, the author has concentrated his attention on the simpler tools of statistics that have been found most readily applicable on a wide scale with a minimum of special training. For production operations, the primary emphasis is on techniques associated with the various Shewhart control charts for controlling quality in process; and, for inspection operations, the emphasis is on acceptance sampling procedures. . . .

The author has brought together under one cover and, in the opinion of the reviewer, skillfully coordinated much of the wartime training material in quality control methods, interweaving the results of his own wide experience in this field as a consultant to industry and as a teacher. The presentation of the control chart techniques, for example, follows closely the tenor and terminology of the A.S.A. War Standards on quality control, notably Z1.3, "Control Chart Method of Controlling Quality During Production," which were promulgated by the War Department to stimulate the varied uses here covered in satisfying detail, and which were used as texts in country-wide intensive training courses. . . .

The subject of acceptance sampling is treated at some length with particular reference to and explanation of (1) the Dodge-Romig sampling tables as applied to receiving, process, and final inspections in a manufacturing plant, and (2) the standard inspection procedures which were developed and widely used during the war by the Army Service Forces, particularly the Ordnance Department, in connection with acceptance inspections of war matériel. With respect to the latter, the material presented is consistent with that used in quality control training programs for Army key inspection personnel. Sequential sampling is touched on briefly, but reference is made to other sources for its application.

Sufficient material on fundamental statistical concepts and probability is included to provide an adequate working knowledge of the underlying principles of the statistical techniques presented in the book. Attention is given to the part that can be played by these techniques in establishing and appraising tolerances. Finally, consideration is given to the general subject of organizing for statistical quality control with recommendations regarding the place that it should take in manufacturing and inspection operations. . . .

One of the outstanding features of the book is its treatment of many excellent examples, a total of 45. This is done realistically and in a way that will appeal to the practical man. The facts of the case are given, then follows the detailed method of approach, results obtained, the action taken, and a thorough discussion of the particular contributions of statistical approach. Moreover, the examples quite generally represent actual problems, not made-up ones. In a number of cases it is refreshing and convincing to find out that there was no gilded Cinderella solution, although there did result a better understanding of the inherent limitations of the manufacturing process. It is of interest to note that the examples cover a wide range of products and topics, such as electrical devices, steel castings, machined parts, textiles, aeroplane components, thermostatic controls, electric cable, discrepancies of gages, overfill of containers, revision of tolerances, and so on.

As the reader goes through the pages, he is exposed to a number of fundamentals that govern the thinking of the quality control engineer as, for example: quality cannot be inspected into a product, it must be built in; some degree of variation in quality is inevitable and must be left to chance; specification tolerances should bear proper relation to the natural tolerances of the process; small sample tests cannot separate good lots from bad but as a series they can tell much about the behavior of the process; it is as important to know when to leave the process alone as to know when it should be corrected; a good sampling plan is often more effective than 100 per cent inspection.

The reviewer has very few critical comments to make. . . . The restrictive statement that the Dodge-Romig tables are designed for use in the situation where the consumer performs the 100 per cent inspection of rejected lots, may be the result of incomplete information, since standard practice in the use of these tables over the years has called for such 100 per cent inspection to be performed by the producer. What is apparently overlooked is that the practice just referred to is readily accomplished by adopting a standard administration procedure; specifically by the adoption of appropriate in-plant rules of procedure, where the producer and consumer are different departments of the same company, or by the use of requirements or contractual agreements involving a system of certification with respect to producer inspections of rejected lots, where the producer is an outside concern.

In summary, this book will be found helpful to all who are concerned with the economic control of quality of manufactured products. For those who ask the question "What is this thing called quality control and is it anything I can use?" the reviewer would class this book as a "must." For the quality control engineer already well advanced in his profession, this book with its wealth of examples and practical suggestions will be enthusiastically received. And for teachers and those responsible for in-plant training programs in quality control, this book with its large number of problems to be solved will be found well suited as a text.

Review by Doris Newman, University of Buffalo

STATISTICAL QUALITY CONTROL, a working manual, summarizes the results of the study and application of statistical quality control. Professor Grant has indicated that this text is aimed at providing a general understanding of the principles underlying the various types of control charts and sampling tables—why the several methods work, how to interpret the results, and how to decide which method to use in any particular case.

The approach followed is to present first the underlying theory, where possible with an intuitive development, then to discuss the applications with examples culled from diverse fields of industrial activity. For classroom use, a series of problems appears at the end of each of the first four parts. Actual data have been used which add to the realistic attitude toward statistical quality control that this book maintains. Advantages and disadvantages of each technique are discussed. In several instances, different methods are applied to the same data to show the comparative efficiency and costs involved. References to original sources appear in footnotes. The text is profusely illustrated with charts and diagrams and standard notation is used throughout—all of which are factors that contribute to great facility in reading the book. The presentation is nonmathematical, but ade-

quate references are given for readers desiring mathematical rigor.

Professor Grant's book stresses the various Shewhart control charts and that portion of sampling theory important in acceptance procedures. Statistical techniques such as regression and correlation which are useful in dealing with special problems of industrial quality control have been omitted. Reference is made to general statistics textbooks containing these topics.

The book contains five parts discussing, in detail, the following topics: Part I—general aspects of control charts; Part II—elements of the theory of frequency distributions; the $\bar{X}$ and R charts, with complete directions for their use; some theory of runs; Part III—about thirty pages on the theory of probability prefacing the discussion on the control chart for fraction defective and the control chart for defects; Part IV—statistical aspects of tolerances; evaluation of quality assurance of sampling plans; single and double sampling; Dodge-Romig tables; acceptance procedures based on control charts for fraction defective, for defects per unit, and for variables. Part V is concerned with cost comparison problems involved in statistical quality control; organization for statistical quality control which considers the complex relationship between the quality control group and management, and the training program needed. The last chapter in Part V discusses the place of statistical quality control in representative manufacturing and inspection operations.

It is to be noted that the theory and interpretation of runs discussed on pages 36, 129, and 245 are not concerned with "runs' as the word is used in the current literature. . . .

Depending on the individual point of view, there may be room for additional criticism. This reviewer feels that this book will be recognized as a valuable text, and is entitled to a place in every library on statistical quality control.

H. J. Gough Receives U. S. Medal of Freedom

THE United States Government has given a high honor to a long-time member of the Society, Dr. Herbert J. Gough, Engineer-in-Chief, Lever Brothers & Unilever Ltd., London, and during the period of the War, Deputy Controller-General of Research and Development, British Ministry of Supply. On August 21, Dr. Gough received on behalf of the President of the United States the Medal of Freedom with Silver Palm for his various and distinctive services during World War II. The citation follows:

Doctor Herbert John Gough, United Kingdom, during the period of active hostilities in World War II, performed exceptionally meritorious service in the field of scientific research and development. An engineer-scientist and leading authority on strength of materials, as Director-General of Scientific Research and Development in the Ministry of Supply, he was responsible for much of the British program for development of ground force weapons, actively cooperating in establishing and supporting, throughout the war, arrangements for the Anglo-American exchange of important relevant information.

The many American friends of Dr. Gough will be very much pleased to learn of this notable recognition of his efforts. He has taken very genuine interest in the work of A.S.T.M., and in 1933 on his visit to the United States he delivered a very notable Edgar Marburg Lecture on "Crystalline Structure in Relation to Failure of Metals—Especially by Fatigue." At that time and for several succeeding years Dr. Gough was Superintendent of the Engineering Department, National Physical Laboratory, Teddington.

Dr. Gough has been much interested in the work of the International Association for Testing Materials, and his efforts contributed in no small measure to the success of the last International Congress held in London in 1937.

Boiler Code Hearing in New York, Nov. 19

IN THE April issue of *Mechanical Engineering* announcement was made by the Boiler Code Committee of The American Society of Mechanical Engineers that its Special Committee to Revise Section VIII of the ASME Boiler Construction Code has prepared and submitted in draft form the Proposed Revision of Section VIII of the Code (Unfired Pressure Vessel Code), dated January, 1947. Public hearings have been held in May at Houston, Texas, and Los Angeles, Calif., where some 250 representatives exchanged views on the proposed revision.

The Boiler Code Committee will hold another public hearing in the East on the Proposed Revision of Section VIII in the Engineering Societies Building, 29 West 39th St., New York, N. Y., on November 19, 1947, at 10:00 a.m. The purpose of this hearing is to give all those interested in the proposed revision an opportunity to express verbally their comments. The Boiler Code Committee is particularly desirous of attracting to this meeting all users of the ASME Unfired Pressure Vessel Code, such as pressure vessel manufacturers and users, representatives from the petroleum industry and state officials.

Those desiring to review the proposed revision may obtain copies from the A.S.M.E. at 29 West 39th St., New York 18, N. Y., at $1.00 each. All those interested are also invited to submit their written comments to the Secretary of the Boiler Code Committee.

J. G. Magrath New Executive Secretary of Welding Society

ANNOUNCEMENT has been received from the American Welding Society of the election of J. G. Magrath to the new office of Executive Secretary by the Board of Directors of the A.W.S. Assuming his duties in September, Mr. Magrath will have associated with him the former staff officers who will continue in their present positions as follows: M. M. Kelly, Secretary; W. Spraragen, Editor of *The Welding Journal* and Director of Welding Research Council; and S. A. Greenberg, Technical Secretary. Formerly connected with the Air Reduction Sales Co., and more recently Sales Manager of the McAleer Manufacturing Div. of Climax Industries, Inc., Mr. Magrath has been since 1917 concerned with welding problems. During World War II he was active in the exploration of welding fabrication and other flame-treatment processing, in shipbuilding and other industrial war plants.

Thousands of Periodicals

Chemical and Engineering News in the July 21 issue has an interesting article by Dr. E. J. Crane, the Editor of *Chemical Abstracts*. This refers to the recently published 209-page List of Periodicals which are abstracted by *Chemical*

Abstracts. For all those who are concerned with information on periodicals, technical journals, etc., which contain material of chemical interest, this list would be helpful. It can be obtained from *Chemical Abstracts*, Ohio State University, Columbus 10, Ohio, at $2 per copy.

Dr. Crane gives an analysis by countries of the sources of periodicals of chemical interest both currently and in 1936. The data are quite significant.

Country	1946		1936	
	No.	%	No.	%
Argentina	77	1.8	30	1.1
Austria	13	0.3	33	1.2
Belgium	58	1.3	44	1.6
Brazil	96	2.2	21	0.7
British Empire	785	18.2	494	18.1
Bulgaria	6	0.1	3	..
Chile	16	0.4	3	..
China	66	1.5	54	1.9
Colombia	11	0.3	1	..
Cuba	13	0.3	3	..
Czechoslovakia	29	0.7	24	0.8
Denmark	41	0.9	24	0.8
Egypt	10	0.2	5	0.1
Federated Malay States	12	0.3	7	0.2
Finland	19	0.4	17	0.6
France	225	5.2	170	6.2
Germany	450	10.4	407	14.9
Hungary	7	0.2	26	0.9
International[a]	47	1.1	8	0.2
Italy	158	3.7	132	4.8
Japan	188	4.4	151	5.5
Mexico	27	0.6	6	0.2
Netherlands	78	1.8	32	1.1
Norway	28	0.6	18	0.6
Peru	18	0.4	3	..
Philippine Islands	13	0.3	8	0.2
Poland	32	0.7	28	1.2
Portugal	14	0.3	4	..
Romania	26	0.6	16	0.5
Spain	37	0.9	23	0.8
Sweden	79	1.8	49	1.7
Switzerland	70	1.6	30	1.1
Turkey	9	0.2	1	..
USSR	334	7.7	201	7.3
United States	1175	27.2	607	22.2
Uruguay	18	0.4	3	..
Venezuela	8	0.2	...	..
Yugoslavia	7	0.2	4	..
All other countries	18	0.4	...	..

[a] International congress publications and the like.

It is indicated that these data are no accurate measure of scientific activity but they do show certain tendencies. The large increase of periodicals in South America, for example, is significant. Percentage figures for the British Empire are the same now as about ten years ago. Of the total given, England has 381 items, Canada 107, and Australia 72. It is noted that about half of the publications appear in English.

An Introduction to Soil Mechanics

THE second edition of this short treatise by Dr. W. L. Lowe-Brown of England on the subject of soil mechanics points out that the field has been flooded with articles and books describing the enormous amount of research in soil mechanics which has been accomplished during the last thirty years. He contends that, unfortunately, these articles and textbooks are written by specialists and research men for one another, and consequently the many busy practicing engineers who long ago have laid aside their higher mathematics, cannot follow the new methods which "bristle with formulae and mathematical operations."

For these reasons the author presents a short descriptive survey which might interest and assist these practicing engineers in the possibilities and limitations of the new field of soil mechanics. The introductory paragraph touches on two of the principal characteristics of soil—internal friction and cohesion, stability of earth slopes and retaining walls. The remaining three chapters include the subjects of compression and consolidation of cohesive material, dams and weirs on permeable foundations and conclude with a caution that sound judgment and wide experience are required in applying the principles of soil mechanics. Four appendices are added dealing with explanation of certain theories and design as applied to specific problems in foundations and retaining wall construction. This book can be obtained at $1.75 per copy from the Pitman Publishing Corp., 2 West 45th St., New York, N. Y.

Pacific Coast Building Officials Conference Holds Silver Anniversary Convention

THE Pacific Coast Building Officials Conference has selected the picturesque and awe-inspiring beauty of the Grand Canyon as the scene of its Twenty-Fifth Annual Business Meeting and Convention, on October 21 to 24. The Hotel El Tovar and the Bright Angel Lodge on the South Rim of the Grand Canyon will be the Convention hotels.

The Pacific Coast Building Officials Conference has been one of the leaders in encouraging the use of modern and uniform building codes. They have consistently recognized the inadequacy of old and antiquated building codes which have been so prevalent in municipalities throughout the country. This inadequacy has been especially critical during the war and postwar years in their lack of recognition of new materials and the many types of prefabricated constructions. The Conference adopted and published in 1946 a revised "Uniform Building Code," which is being used by many municipalities, not only on the West Coast, but throughout the country.

There has been a very close relationship between the Conference and A.S.T.M., inasmuch as there is a common interest in promoting the use of standard and uniform specifications. The Conference has made extensive usage of the many A.S.T.M. Standards covering construction materials throughout their publication. There is included a ready reference table noting all A.S.T.M. references, as well as those of other specification-writing organizations.

Wood Samples Available

ANNOUNCEMENT has been received from E. George Stern, Director of the Wood Research Laboratory, Engineering Experiment Station, Virginia Polytechnic Institute, Blacksburg, Va., that the Laboratory can supply for a charge of $2 per set a limited number of collections of 40 wood samples, the sample size being 4½ by 2½ by ½ in. Each sample is labeled with the common and botanical name of the tree and wood, with information on the range and use of the particular species.

South African Standards for Ferro-Alloys

THAT A.S.T.M. Standards can have a far-reaching effect is shown by a number of specifications for ferro-alloys which the Society recently received from the South African Bureau of Standards, with headquarters in Pretoria, South Africa. These are in draft form and are specifications for ferrochromium, ferromanganese, ferrosilicon, and silico-ferromanganese. These South African Standards follow closely A.S.T.M. Committee E-3's Methods for Chemical Analysis, but in the composition of some of the alloys differ from A.S.T.M. Standards written by Committee A-9 because the South African Standards were designed to take care of locally available ores.

Canadian Standards

THROUGH the work of the Canadian Standards Association, Ottawa, there have recently been issued some codes and standards which may be of interest to a number of our members. A list of these items follows:

	Cost
B 75-1947—Code of Practice for the Use and Care of Chain.	50 cents
C22.1-1939—Canadian Electrical Code, Part I (Fifth Edition)—Essential Requirements and Minimum Standards Governing Electrical Installations for Buildings, Structures and Premises—All Potentials.	$1.00
C22.3 No. 1(C)—Rules, Requirements and Specifications for the Construction of Supply Lines Crossing Communication Lines.	$1.00
C22.4 No. 108—Construction and Application of Suppressors for Radio Interference.	50 cents
W47-1947—Welding Qualification Code for Application to Fabricating and Contracting Firms Their Welding Personnel and Equipment.	75 cents
W48-1947—Standard Specification for Iron and Steel Arc-Welding Electrodes.	75 cents

New Members to September 30, 1947

The following 123 members were elected from July 7 to September 30, 1947, making the total membership 6354.

Names are arranged alphabetically—company members first, then individuals.

Chicago District

BADGER DIE CASTING CORP., R. C. Strassman, Secretary-Treasurer, 201 W. Oklahoma Ave., Milwaukee 7, Wis.

MCGRAW ELECTRIC CO., Philip E. Willman, Asst. Chief Engineer, Research and Development Dept., 5201 W. Sixty-fifth St., Chicago 38, Ill.

MILWAUKEE ELECTRIC RAILWAY AND TRANSPORT CO., THE, F. G. Hibbard, Asst. Engineer of Way and Structures, 940 W. St. Paul Ave., Milwaukee 3, Wis.

MILWAUKEE MALLEABLE AND GREY IRON WORKS, C. A. Gutenkunst, Jr., President, 2773 S. Twenty-ninth St., Milwaukee 7, Wis.

ROTH RUBBER CO., W. W. Knight, President, 1860 S. Fifty-fourth Ave., Cicero 50, Ill.

BECKWITH, H. R., Plant Manager, Reliance Varnish Co., 4501 W. Haddon Ave., Chicago, Ill.

CHILDS, LEONARD C., Partner, Battey & Childs, 231 S. LaSalle St., Chicago 4, Ill.

DRESHFIELD, ARTHUR C., Chemical Engineer Consultant, 401 W. Elm Ave., LaGrange, Ill.

OSTERBERG, J. O., Assistant Professor of Civil Engineering, Technological Institute, Northwestern University, Evanston, Ill.

SANFORD, FRANK E., Director of Research, Copper Wire Engineering Assn., 20 N. Wacker Dr., Chicago 6, Ill.

ZAGIELSKI, KENNETH C., Laboratory Technician, Crane Co., 4100 S. Kedzie Ave., Chicago, Ill. For mail: 204 S. Madison Ave., LaGrange, Ill. [J]*

Cleveland District

CLEVELAND CAP SCREW CO., THE, W. C. Cooke, Metallurgist, 2917-23 E. Seventy-ninth St., Cleveland 4, Ohio.

VAN HORN, K. R., Chief, Cleveland Research Division, Aluminum Research Laboratories, Aluminum Company of America, 2210 Harvard Ave., Cleveland 5, Ohio.

Detroit District

FORD MOTOR CO., John L. McCloud, Chemical Engineer, Dearborn, Mich. [S]**

WYANDOTTE PAINT PRODUCTS CO., C. W. Oliver, General Manager, 1430 Sycamore St., Wyandotte, Mich.

KENNEDY, F. C., Development Engineer, U. S. Rubber Co., 6600 E. Jefferson, Detroit 32, Mich.

PATTERSON, DONALD, Chief Engineer, Hunt & Patterson, Box 73, Ferndale 20, Mich.

SUTER, HAROLD R., Assistant to Director of Research, Wyandotte Chemicals Corp., Wyandotte, Mich.

SWITZER, MARSHALL H., Technical Associate, C. Olin Ball, Consulting Food Technologist, 408 E. Broadway, Maumee, Ohio. For mail: 3943 Bowen Rd., Toledo 6, Ohio.

New England District

ANDERSON OIL CO., F. E., Arnold W. Ackerman, Chief Chemist, Box 266, Portland, Conn.

BOWSER INC., REFRIGERATION DIVISION, Thomas J. Lopiccolo, Chief Engineer, Terryville, Conn.

HOLYOKE WIRE AND CABLE CORP., Elmer S. Bartlett, Assistant General Manager, 720 Main St., Holyoke, Mass.

New York District

BURNS & ROE, INC., Robert F. Cummings, Vice-President, 233 Broadway, New York 7, N. Y.

FOSTER WHEELER CORP., Martin Frisch, Vice-President, 165 Broadway, New York 6, N. Y.

AUFHAUSER, DAVID, Consulting Chemist, 64 Riverside Dr., New York 24, N. Y.

BIXLER, HARRY C., Assistant to the President, Limestone Products Corp. of America, 122 Main St., Newton, N. J. For mail: 76 Ryerson Ave., Newton, N. J.

BROOKLYN, PRESIDENT OF THE BOROUGH OF, Charles A. Riedel, Chief Engineer, Bureau of Highways and Sewers, 900 Municipal Bldg., Brooklyn 2, N. Y.

CORLEY, ROBERT N., Railroad Sales Representative, The Corley Co., Inc., 629 Grove St., Jersey City, N. J.

HOLLABAUGH, CLEVELAND B., Research Chemist and Patent Attorney, The Dentists' Supply Co. of New York, 220 W. Forty-second St., New York, N. Y. For mail: 112-27 177th St., St. Albans, L. I., N. Y.

JONES, HENRY WARE, III, Assistant Chief Engineer, American Tube Bending Co., Inc., 5 Lawrence St., New Haven 11, Conn.

MARSHACK, EUGENE, Executive Engineer, Bunge Corp., 80 Broad St., New York 4, N. Y.

MUDGE, W. A., Director, Technical Service on Mill Products, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

NORWICK, BRAHAM, Laboratory Director, Beaunit Mills, Inc., 450 Seventh Ave., New York 1, N. Y.

OLMSTEAD, PAUL S., Statistical Consultant, Bell Telephone Laboratories, Mountain Ave., Murray Hill, N. J.

PELTON, B. W., Officer-in-Charge; Colonel, Quartermaster Corps Inspection Service, 111 E. Sixteenth St., New York 3, N. Y.

ROCHOW, THEODORE GEORGE, Chemical Microscopist, American Cyanamid Co., Stamford, Conn.

Northern California District

CONNER, RALPH N., Sales Engineer, the Baldwin Locomotive Works, 2929 Nineteenth St., San Francisco 10, Calif.

ROBERTS, WALTER C., Director, Pacific Engineering Laboratory, 604 Mission St., San Francisco 5, Calif.

SAN FRANCISCO, CITY AND COUNTY OF, PUBLIC UTILITIES COMMISSION, ENGINEERING BUREAU, A. O. Olson, Manager and Chief Engineer, 425 Mason St., San Francisco 1, Calif.

Philadelphia District

PEZZILLO PUMP CO., D. P. Litzenberg, Chief Engineer, 1343 W. Cumberland St., Philadelphia 32, Pa.

SUMMERILL TUBING COMPANY DIVISION, A. J. Williamson, Plant Manager, Bridgeport, Pa.

WARREN FOUNDRY AND PIPE CORP., Thomas R. Walker, Jr., General Superintendent, Phillipsburg, N. J.

ALKUS, WILLIAM, Vice-President, Richmond Oil, Soap and Chemical Co., Inc., 1041 Frankford Ave., Philadelphia 25, Pa.

BOGGS, IRVING H., Bituminous Concrete Engineer, the General Crushed Stone Co., Drake Bldg., Easton, Pa.

MAXWELL, BRYCE, Research Assistant, Princeton University, Princeton, N. J. For mail: Plastics Laboratory, 30 Charlton St., Princeton, N. J.

WILLIAMS, WILLIAM A., Chief Engineer, American Pulley Co., 4200 Wissahickon Ave., Philadelphia 29, Pa.

Pittsburgh District

DRASTRUP, A. B., Manager, Alloy and Stainless Steel Sales, A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

GRUMBLING, J. S., Assistant Chief Metallurgist, Sharon Steel Corp., Sharon, Pa.

MCCLUSKEY, WILLIAM OLIVER, JR., President, Consolidated Engineering Co., 17th and Warren St., Wheeling, W. Va. For mail: Box 409, Wheeling, W. Va.

MEARS, R. B., Manager, Research Laboratory, Carnegie-Illinois Steel Corp., 210 Semple St., Pittsburgh 13, Pa.

MORGAN, WILLIAM J., Metallurgical Observer, Carnegie-Illinois Steel Corp., Edgar Thomson Works, Braddock, Pa. For mail: 2200 Walton Ave., Pittsburgh 10, Pa.

ORNITZ, MARTIN N., Assistant Chief Metallurgist, National Alloy Steel Division of Blaw-Knox Co., Blawnox, Pa. [J]

ROW, K. R. NARAYANA, Graduate Student, Carnegie Institute of Technology, Pittsburgh 13, Pa. [J]

SCOTT, R. K., Research Engineer, Hall Laboratories, Inc., Box 1346, Pittsburgh 30, Pa.

St. Louis District

WAGNER MALLEABLE IRON CO., John A. Wagner, President, 1275 E. Sangamon, Decatur 2, Ill.

BALDRIDGE, W. M., Research Engineer, Laclede Steel Co., Alton, Ill.

RATHELL, WALTER P., Chief Engineer, Missouri Rolling Mill Corp., 6800 Manchester Ave., St. Louis 10, Mo.

ZANGE, MAX, Chief, Preventive Maintenance Branch, Granite City Engineer Depot, War Dept., St. Louis, Mo. For mail: Warwick Hotel, 15th and Locust Sts., St. Louis, Mo.

Southern California District

ARROWHEAD RUBBER CO., Jack Wurtz, Chief Chemist, 2244 E. Thirty-seventh St., Vernon 11, Calif.

HINSHAW, JERROLD O., Chief Chemist, Purex Corp., Ltd., 9300 Rayo Ave., South Gate, Calif.

MACKINTOSH, ALBYN, Partner, Mackintosh & Mackintosh, 306 N. Vermont Ave., Los Angeles 4, Calif.

WASHBURN, HAROLD W., Vice-President, Research, Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena, Calif.

Western New York and Ontario District

AMERICAN LUBRICANTS, INC., Melville Ehrlich, Chief Chemist, 1575 Clinton St., Buffalo 6, N. Y.

FARNHAM, GORDON STUART, Chief, Development and Research Section, International Nickel Co. of Canda, Ltd., 25 King St., W. Toronto, Ont., Canada.

U. S. and Possessions

CLUETT, PEABODY AND CO., INC., H. R. Bellinson, Superintendent, Standards Testing Lab., 433 River St., Troy, N. Y. [S]

CORDUROY RUBBER CO., A. F. Rausell, Chief Chemist, Fuller Ave., N. E., Grand Rapids 1, Mich.

DAVIS CO., H. B., THE, Harry Feinberg, Technical Director, Bayard and Severn Sts., Baltimore, Md.

DAYTON MALLEABLE IRON CO., THE, Harold Saurer, Chief of Metallurgy, Box 980, Dayton 1, Ohio.

DU PONT DE NEMOURS AND CO., INC., E. I., ACETATE RESEARCH LIBRARY, Mrs. Anne Luke, Librarian, Waynesboro, Va.

FIBER MANUFACTURING CO., A. A. Kuhn, Treasurer, Newton, N. C.

GENERAL TEXTILE MILLS, INC., Thomas H. Garber, Assistant to the President, Carbondale, Pa.

HANNA PAINT MANUFACTURING CO., THE, Chester A. Olson, Chief Chemist, 95 W. Long St., Columbus 15, Ohio.

NORGE MACHINE PRODUCTS DIVISION, BORG-WARNER CORP., Leland K. Warrick, Chief Engineer, 2696 Lake Shore Dr., Muskegon, Mich.

TEXAS FOUNDRIES, INC., Cal C. Chambers, President and General Manager, Box 180, Lufkin, Tex.

BENNETT, EARL F., Principal Soil Engineer, Bureau of Soil Mechanics, New York State Department of Public Works, Gov.

Alfred E. Smith State Office Bldg., Albany 1, N. Y.

BIRKENWALD, E. S., Engineer of Bridges, Southern Railway System, 307 E. Fourth St., Cincinnati 2, Ohio.

BUCK, GEORGE S., JR., Technical Service Director, National Cotton Council of America, Memphis 1, Tenn. For mail: 1406 G St., N. W., Washington 5, D. C.

BURROWS, MARTIN E., Test Engineer, General Electric Co., Schenectady, N. Y. For mail: 241 Highwood Ave., Ridgewood, N. J. [J]

COLIN, EDWARD CECIL, JR., Research Assistant, University of Illinois, Urbana, Ill. For mail: 410 Chalmers St., Champaign, Ill. [J]

COLLIER, CHARLES VINES, JR., Consulting Practice, 301 E. Fern St., Tampa 4, Fla.

COLUMBUS, CITY OF, ENGINEERING DEPT., City Engineer, Court House, Columbus, Ga.

CRONIN, DAVID I., Research Director, Univis Lens Co., 401 Leo St., Dayton 1, Ohio.

DIER, CLIFFORD L., Consulting Engineer, Harold Hoskins and Associates, Inc., 229 N. Eleventh St., Lincoln 8, Nebr.

DIES, A. S., Chief Chemist, Canada Cement Co., Ltd., Phillips Square, Montreal 2, P. Q., Canada.

FRYER, RICHARD R., Technical Director, Wolverine Chemical Co., Box 382, St. Joseph, Mich.

GONGWER, L. F., Manager, Development Dept., J. M. Huber Corp., Borger, Tex.

GOSHORN, J. H., Assistant Chief Engineer, Ohio State Highway Testing and Research Laboratory, Ohio State University Campus, Columbus, Ohio.

HRONIK, RICHARD H., Equipment Engineer, Army-Navy Medical Procurement Office, Engineering Development Division Laboratory and Shop Branch, Carlisle Barracks, Pa.

HYATT, CHARLES S., Vice-President, Columbus Coated Fabrics Corp., Seventh and Grant Aves., Columbus, Ohio.

JEFFERSON, MERRILL E., Physicist, Southern Regional Research Laboratory, 2100 Robert E. Lee Blvd., New Orleans 19, La. For mail: 6057 Louisville St., New Orleans 19, La.

JONES, J. ARNOLD, Sales Manager, Everybody's Oil Corp., 1001 Fletcher St., Anderson, Ind. For mail: Box 587, Anderson, Ind.

KETCHBAW, THOMAS E., Laboratory Manager, Industrial Welding and Testing Laboratory, 224 Hamilton St., Houston, Tex. For mail: 6619 Lozier St., Houston, Tex.

LEWIS, WAYNE C., Engineer, U. S. Forest Products Laboratory, Madison, Wis.

MARQUETTE, CITY OF, DEPARTMENT OF PUBLIC WORKS, J. A. Clulo, City Engineer, City Hall, Marquette, Mich.

MCCORMICK, LEWIS MONTFORD, Chemist and Tester of Rubber and Rubber-Like Products, Allison Division, General Motors Corp., Indianapolis, Ind. For mail: Box 64, Indianapolis 6, Ind.

MCRAE, JOHN C., Director, Washington Testing and Engineering Services, 1756 Arlington Ridge Rd., Arlington, Va.

MILLS, WILLIAM HAYNE, Chief, Airport Engineering and Construction Division, Civil Aeronautics Administration, 84 Marietta St., N. W., Atlanta, Ga.

PETTS, R. G., Supervisor of Quality Control, Sylvania Electric Products, Inc., Plant 1, Williamsport, Pa.

POWELL, DONALD E., Chemist, Susquehanna Collieries Co., 8 W. Main St., Nanticoke, Pa.

PURDUE UNIVERSITY, JOINT HIGHWAY RESEARCH PROJECT, K. B. Woods, Associate Director, Civil Engineering Bldg., Lafayette, Ind.

ROBY, L. E., JR., Superintendent, Peoria Malleable Castings Co., Peoria 1, Ill. For mail: Box 597, Peoria 1, Ill.

SCHMIDT, A. W., Acting Chief, Power Operating and Maintenance Division, U. S. Bureau of Reclamation, Interior Bldg., Washington 25, D. C.

SEELEY, SHERRILL, Head Chemist, Skenandoa Rayon Corp., 1201 Broad St., Utica 2, N. Y.

SHELTON, CHARLES L., Textile Engineer, Nye-Wait Co., Inc., Auburn, N. Y.

UNIVERSITY OF CHATTANOOGA, INDUSTRIAL RESEARCH INSTITUTE, J. H. Coulliette, Chattanooga 3, Tenn.

WOFFORD COLLEGE LIBRARY, James C. Loftin, Associate Professor of Chemistry, Spartanburg, S. C.

WOOD, LYMAN W., Civil Engineer, U. S. Forest Products Laboratory, Madison 5, Wis.

Other than U. S. Possessions

FALKNOVSKÉ HNEDOUHELNÉ DOLY, NÁRODNI PODNIK, Josef Formánek, General Manager, Falknov n. O., Czechoslovakia.

INDUSTRIA ELÉCTRICA DE MÉXICO, S. A., Tomas Rodriguez V, Divisional Engineer, Avenida Morelos 110, Mexico, D. F., Mex.

LABORATORIO CALCI E CEMENTI DI SEGNI, A. Creseto, Colleferro, Rome, Italy.

THELWALL, LTD., KENNETH, Robert Todd, Chief Chemist, Churchill Rd., Doncaster, Yorkshire, England.

BECKER, MAURICE LUND, Superintendent, British Iron and Steel Research Assn., 11 Park Lane, London W. 1, England. For mail: 68 Hurst Rd., East Molesey, Surrey, England.

CASTRO, RENE J., Head of Research Laboratories, Aciéries Electriques d'Ugine, Ugine, Savoie, France. For mail: Les Charmettes, Ugine, Savoie, France.

HARRIS, HERBERT, Works Metallurgist, Babcock & Wilcox, Ltd., Renfrew, Scotland.

HERMANN, GUNTER, Technical Manager, Cristais Prado Ltda., Av. Celso Garcia 1467, Brazil. For mail: Rua Nacaia No. 18, São Paulo, Brazil.

NELLENSTEYN, F. J., Director, Rijkswegenbouwlaboratorium, Badhuiskade 21, 's-Gravenhage, Holland.

NOKIN, MAX, Managing Director, Cimenteries et Briqueteries Reunies, 3 Montagne du Parc, Brussels, Belgium.

OWEN, STANLEY F., Executive Engineer, Public Works Department, Head Office, Kuala Lumpur, Selangor, Malaya, India.

PELISCH, JOHN, Technical and Consulting Chemist, Swiss-Argentine Industrial and Chemical Laboratories, 669 Chacabucost, Buenos Aires, Argentina.

PULIDO Y MORALES, RENÉ' S., Chief Engineer, Soil Laboratory, Public Works Dept., 10 No. 55 Vedado, Havana, Cuba.

SHANNON, WILLIAM BOYD, Chief Assistant Constructional Engineer, London Power Co., Ltd., Ergon House, Horseferry Rd., London S. W. 1, England.

TENNEY, GEROLD H., Groupleader, Los Alamos Scientific Laboratory, Box 1663, Los Alamos, N. Mex.

VARGAS, JOAQUIN, Chemical Engineer, Ingenieria Industrial S. A., Apartado 2830, Lima, Peru. For mail: Av. 6 de Agosto 1135, Lima, Peru.

* [J] denotes Junior Member.
** [S] denotes Sustaining Member.

Personals. . .

ROY W. CRUM, Director of the Highway Research Board of the National Research Council, recently received the Iowa State College Alumni Merit Award from the Alumni Club of Chicago, the award being bestowed upon outstanding alumni for meritorious service in their fields. Affiliated with A.S.T.M. since 1911, Mr. Crum has been active in several of our technical committees for many years.

ARPAD L. NADAI, Consulting Engineer of the Westinghouse Research Laboratories, E. Pittsburgh, Pa., has been awarded the Worcester Reed Warner Medal, honoring noteworthy contributions to the permanent literature of engineering, by The American Society of Mechanical Engineers. Dr. Nadai will receive the Medal formally at the Society's annual meeting in Atlantic City in December. Dr. Nadai earlier this year delivered the James Clayton Lecture before the British Institution of Mechanical Engineers in London and Manchester. His paper on the plastic flow of metals, in which field he is an internationally known specialist, won the acclaim of scientists in England and on the Continent. Dr. Nadai has been much interested and active in various phases of A.S.T.M. work, and in 1931 he delivered the A.S.T.M. Marburg Lecture on "The Phenomenon of Slip in Plastic Materials."

F. P. ZIMMERLI, Chief Engineer, Barnes-Gibson-Raymond, Division of Associated Spring Corp., Detroit, has been elected to receive the Albert Sauveur Award, highest for technical achievement conferred by the American Society for Metals. The citation reads "for his basic research in the field of shot peening to increase favorable stresses in the surfaces of metal parts." Mr. Zimmerli has been representative of the Barnes-Gibson-Raymond Division A.S.T.M. membership since 1929, has been active in Committees A-1, B-4, and E-9 for many years, and is presently Vice-Chairman of the Detroit District Council.

C. H. SAMANS has been named Chief of the Metallurgical Section of American Optical Co.'s Research Laboratory, Southbridge, Mass. Dr. Samans joined American Optical Co.'s Research Laboratory in 1931 as Research Metallurgist.

WALTER J. RILEY has been appointed Divisional Sales Manager in charge of the Technical Sales Division, Westvaco Chlorine Products Corp., New York City. Associated with the company since 1936 in various technical and research activities, Mr. Riley was most recently Assistant to the Technical Director in New York. A member of the newly formed A.S.T.M. Committee on Magnesium Oxychloride Cement, he has been named Chairman of the Subcommittee on Methods of Test.

WILFRED F. GILLESPIE, Technical Director, Gaylord Container Corp., Bogalusa, La., has been designated as President of the Technical Association of the Pulp and Paper Industry since that office was left vacant by the sudden death of Worthen E. Brawn.

GEORGE R. THOMPSON, City Engineer of Detroit, Mich., has been elected President of the Engineering Society of Detroit. Mr. Thompson is a member of A.S.T.M. Committee C-6 on Drain Tile, representing the American Public Works Assn.

DR. CHARLES F. KETTERING, a member of A.S.T.M. for many years, has retired as Vice-President in Charge of Research Labs., General Motors Corp. having reached the normal retirement age. Dr. Kettering has been associated with General Motors since 1920, when the Dayton Research Laboratories, of which

he was a co-founder, were acquired by the Corporation. During his work with Dayton and later with General Motors, projects of far-reaching significance have been developed. He has also done pioneering work in the field of medical research. He will remain a Director of General Motors and also serve as a Consultant. Charles L. McCuen, Vice-President in Charge of the Engineering Staff, will succeed Dr. Kettering as General Manager of Research Labs. Div., and James M. Crawford, who had been General Assistant to Mr. McCuen, has been elected Vice-President in Charge of Engineering Staff.

CLARENCE H. LORIG and RALPH A. SHERMAN, together with four other veteran members of the Battelle Memorial Institute staff, have been named new Assistant Directors, this action representing a step in the development of the Battelle plan of research operation, under which departmental lines are merely nominal and full coordination of research is achieved by joint attack of problems by all qualified members.

WILLIAM J. GREDE, President, Grede Foundries, Inc., Milwaukee, has been elected as class B Director of the Federal Reserve Bank of Chicago.

L. P. McALLISTER, active in the work of Committee A-1 on Steel, has been appointed Assistant Manager, Lukens Steel Co., Coatesville, Pa. He was formerly Metallurgical Engineer.

WILLIAM A. HAMOR, Assistant Director of Mellon Institute of Industrial Research, Pittsburgh, was given the honorary degree of Doctor of Science at the commencement of the University of Louisville. Dr. Hamor has been affiliated with A.S.T.M. since 1922.

M. J. DeFRANCE, a representative of Goodyear Tire & Rubber Co., Akron, Ohio, on Committee D-11 since 1938, has been promoted to Assistant Manager of the Development Department of the Chemical Products Division. Mr. DeFrance has been with Goodyear for 18 years. He and Ian D. Patterson, the newly appointed Manager of the Department, will supervise development work on compounding, adhesives and coatings, Pliofilm packaging, and other chemical product activities.

BRADLEY DEWEY, President of the Dewey & Almy Chemical Co., Cambridge, Mass., has received the Medal of Merit, one of the nation's highest awards, for his outstanding services to the United States as Deputy Rubber Director from 1942 to 1943, and as Rubber Director from 1943 to 1944, and for his services as Chairman of the Guided Missiles Committee of the Joint Chiefs of Staff.

WILLIAM M. MURRAY, JR., Acting Head of the Engineering Division of the Southern Research Institute, Birmingham, Ala., has been appointed Assistant Director of the Institute.

LOUIS J. ROHL has been appointed Chief Metallurgical Engineer of Carnegie-Illinois Steel Corp. He had been Assistant Chief Metallurgical Engineer since last April, and associated with the company since 1917.

The NON-FERROUS INGOT METAL INSTITUTE, Chicago, has announced the appointment of Isadore Glueck as Secretary-Manager, succeeding R. D. T. Hollowell, who has retired following 20 years in that position.

JOSEPH J. MAYER has been elected Vice-President and a Director of the Lumen Bearing Co., Buffalo, to succeed the late C. H. Bierbaum. Mr. Mayer will continue to serve as General Superintendent.

HAROLD O. HILL, Assistant Chief Engineer, Fabricated Steel Construction, Bethlehem Steel Co., Bethlehem, Pa., has been nominated for the Presidency of the American Welding Society; and O. B. J. FRASER, Asst. Manager, Development and Research Div., The International Nickel Co., New York City, is the nominee for Second Vice-President. Nominees for Directors-at-Large include David Arnott, Vice-President and Chief Surveyor, American Bureau of Shipping, New York City.

HERBERT C. HALLER has recently joined the Forstmann Woolen Co., Passaic, N. J., as Assistant Director of Research. He comes from Continental Mills in Philadelphia, where he was Chief Chemist for the past nine years.

PHILIP SPORN has been elected President of the American Gas and Electric Co. and of its engineering and management subsidiary, the American Gas and Electric Service Corp., New York City. He joined the staff of the organization in 1920, becoming Chief Engineer in 1933 and Vice-President in charge of all engineering operations in 1934. Mr. Sporn received the 1945 Edison Medal of the A.I.E.E. and the 1946 Egleston Medal of Columbia University for his contributions in the field of utility engineering. He has been active for many years on A.S.T.M. Committees A-5 and D-9.

Macy's in numerous ads has been stressing the work of its Bureau of Standards which this year celebrates its 20th Anniversary. The big display in *The New York Times* of Tuesday, August 12, was in a sense a tribute to the Macy's Bureau of Standards Director who established it, EPHRAIM FREEDMAN, very active in many phases of A.S.T.M. work. Through an innocent slip of printing, the ad is more than a tribute because there is a special P.S., in part reading as follows: "Happy testing, Eph, and our apologies for breaking your perfect record. (This P.S. is the only part of a Macy ad in twenty years that you didn't see before publication.)"—but earlier in the P.S. they misspelled his first name "Ephriam"!

The advertisement shows many special devices for carrying out the test work for which Macy's is famous.

ROBERT JOB, for many years Vice-President of the Milton Hersey Co., Ltd., Montreal, leading inspecting and testing engineers in Canada, has retired from his position, although he is still connected with the company. One of the very long-time members of A.S.T.M., his personal membership dates from 1900. Down through the years he has been affiliated with a large number of technical committees and he took a most active part in specifications work, particularly in the ferrous metal committees. He presented a number of technical papers which appeared in early *Proceedings* dealing with locomotive materials, rails, the evaluation of paints, etc. Mr. Job will continue to reside in the vicinity of Montreal, his address being 649 Roslyn Ave., Westmount, Province of Quebec.

RALPH WILCOX, heretofore Production Superintendent at the Detroit plant of Gerity-Michigan Die Casting Co., has been named Manager of the Detroit division. Mr. Wilcox is a member of Committee B-6 on Die-Cast Metals and Alloys.

THOMAS R. C. WILSON, former Chief of the U. S. Forest Products Laboratory Division of Timber Mechanics, Madison, Wis., has been appointed Secretary-Treasurer of the Forest Products Research Society. Mr. Wilson, now in charge of the Society's permanent office in Madison, also will continue his consulting timber engineering practice. Announcement of the appointment was made by FRED W. GOTTSCHALK, Chicago, President of the Society and Technical Director of the American Lumber and Treating Co., following action of the executive board. Information from this relatively new society indicates that their membership has grown to about 600; their first annual meeting is to be held in Chicago, October 31 and November 1. Both Mr. Wilson and Mr. Gottschalk are active in A.S.T.M. Committee D-7 on Wood.

EDWARD T. BARRON for many years Chief Metallurgical Engineer of Carnegie-Illinois Steel Corp. has retired from service with the company. However, he has undertaken certain studies for the United States Government in Japan and expects to be abroad for about four months or so. He has been interested in the A.S.T.M. organization for many years and his present membership dates from 1916.

J. H. CRITCHETT, formerly Vice-President of the Union Carbide and Carbon Research Laboratories, Inc., has retired from the company and has also relinquished his committee memberships and work in A.S.T.M. He has been interested in many phases of the Society's technical work and was chairman of Committee A-9 on Ferro-Alloys, in addition to serving on Committee A-1 on Steel, and the Joint A.W.S.-A.S.T.M. Committee on Filler Metal. With the Electro Metallurgical Co. from 1914 to 1921, he was with the Union Carbide and Carbon Research Laboratories since 1921. Very active in the work of many societies, and Past-President of the Electrochemical Society, he will make his home in Orleans, Mass.

EDWARD CECIL COLIN, JR., formerly Research Assistant, University of Illinois, Urbana, is now Draftsman with Perkins & Will, Architects, Chicago.

GEORGE W. BORTON, member of A.S.T.M. since 1909, has retired as President and General Manager of the Pennsylvania Crusher Co., Philadelphia, Pa.

HENRY MUSCH, III, is now Production Engineer, Marlin Firearms Co., New Haven, Conn. He was formerly with A. E. Broughton & Co., Mt. Carmel, Conn.

A. H. FLOWER has retired as Director of Research and A.S.T.M. Company Representative of the Inland Manufacturing Div., General Motors Corp., Dayton, Ohio. Dr. Flower has been active for many years in A.S.T.M. Committee D-11 on Rubber and Rubber-Like Materials.

FRANK K. SAVAGE has left the Kuehne Mfg. Co., Mattoon, Ill., and is now Asst. to the Vice-President, Standard Plating Rack Co., Chicago.

SIDNEY WENIGER, formerly Plant Engr., Cleaveland Labs. & Mfg. Co., Inc., Peapack, N. J., is now affiliated with Sheffield Farms Co., Inc., Merrick, N. Y. as Construction Engr.

C. A. HUGHES has been appointed Professor of Structural Engineering, Purdue University, Lafayette, Ind. He was previously Associate Professor of Structural Engineering at the University of Minnesota.

CHARLES E. SCHAFFNER, recently of the U. S. Army, has returned to civilian life and is now Assistant Professor, Department of Civil Engineering, Polytechnic Institute of Brooklyn.

FRANCIS B. FOLEY, Superintendent of Research, The Midvale Co., Philadelphia, has been nominated for President of the American Society for Metals, with election to be confirmed at the Annual Meeting in late October in Chicago at the National Metal Congress. Very active in A.S.T.M. work, with a wide circle of friends in the Society, he is completing a term as A.S.M. Vice-President. H. K. WORK, Manager of Research and Development, Jones and Laughlin Steel Corp., Pittsburgh, will be the new A.S.M. Vice-President. Mr. Work has been a member of A.S.T.M. since 1924.

GEORGE B. WATERHOUSE, Past-President of the American Society for Metals and Emeritus Professor of Metallurgy, Massachusetts Institute of Technology, is at present in Bogota, Colombia, where, at the request of the Colombian government, he will investigate the feasibility of establishing a steel plant. Professor Waterhouse is a long-time A.S.T.M. member and an active participant in various technical committee activities.

C. W. WHEATLEY, who has been Laboratory Director at the A. O. Smith Corp., Milwaukee, has been appointed General Manager of the firm's plant at Houston. Mr. Wheatley has been representative of the Smith Corp. A.S.T.M. membership for many years, serving on Committees A-1, A-10 and E-7.

EDWIN F. CONE has retired from his editorial work on *Materials and Methods*. He became editor of its predecessor, *Metals and Alloys*, in 1935 after having spent about 20 years on the editorial staff of *Iron Age*. He was particularly interested in the foundry industry and in this connection, has served for many years on A.S.T.M. Committee A-3 on Cast Iron. A long-time A.S.T.M. member, he has always taken a very genuine interest in the Society's work.

Announcement has been received from DR. LEROY W. SHUGER, Technical Director, Baltimore Paint & Color Works, of a course in paint, varnish and lacquer technology, to be given at Johns Hopkins University, Wednesday evenings, the first lecture scheduled for October 1. DR. WILLIAM T. PEARCE, Consultant on Organic Coatings, and very active in the work of A.S.T.M., is the permanent lecturer in this course. Dr. Pearce was formerly Dean of Chemistry at North Dakota State College.

EUGENE E. LORENCE has opened the Lorence Studio of Photography, Buffalo, N. Y. He was formerly Chemist with the Linde Air Products Co., Tonawanda, N. Y.

RAYMOND H. PIERSON has been transferred from the U. S. Naval Drydocks, San Pedro, Calif., to the Naval Ordnance Test Station, Inyokern, Calif.

GEORGE H. ROBINSON, formerly with the Attock Oil Co., Ltd., Rawalpindi, India, is now associated with the Burma Cement Co., Ltd., Thayetmyo, Burma.

EDWIN S. WORDEN, JR., has announced opening of his own offices as Packaging and Materials Consultant, White Plains, N. Y. He was previously affiliated with Edgar Steiner & Co., New York City, as Research Engineer.

W. S. JAMES, formerly Specification Writer with the United Rexall Drug Co. and the Fluor Corp. of Los Angeles, Calif., is now associated with Bennett & Bennett, Architects, Pasadena, in a similar capacity.

PIETER HONIG is now in Batavia, Java, as Commissioner for the Netherlands East Indies Institute for Rubber Research. He was formerly Commissioner, Board for Netherlands Indies, Surinam & Curacao, New York.

J. EDWARD FAUSER has retired as Technical Adviser for E. I. du Pont de Nemours and Co., Inc., Chicago. Mr. Fauser has rendered active service on Committee D-1 on Paint, Varnish, Lacquer, and Related Products since 1925.

GEORGE N. THOMPSON, formerly Chief, Div. of Codes and Specifications, National Bureau of Standards, Washington, D. C., is now Assistant Chief of the newly organized Building Technology Division of the Bureau.

J. LEWIS LUCKENBACH is now Designing Engineer, Russel and Axon, Daytona Beach, Fla. He was formerly associated in a similar capacity with Hardy S. Ferguson and Co., Inc., of New York City.

RAUL VALLE-RODAS, previously with Embajada de Bolivia, Caracas, Venezuela, is now Soils Engineer, Direccion De Obras de Riego Ministerio de Obras Publicas, in the same city.

E. V. ROMAINE, recently of the Carmody Research Labs., Inc., Philadelphia, Pa., is now Manager, Technical Sales, Pennsylvania Industrial Chemical Corp., Clairton, Pa.

CHARLES J. HUBER, formerly engaged in private practice in Plainfield, N. J., is now Consulting Engineer with Sanderson and Porter, New York City.

N. AUSTIN ELLMORE is now associated with the Crescent Industries, Chicago, Ill. He was formerly connected with the Utah Radio Prod. Div. of International Detrola Corp., Detroit.

S. D. HERON, formerly Engineer with the Ethyl Corp., Detroit, has opened his own offices as Consulting Engineer in the same city.

ROBERT H. HEDRICK has joined the staff of Calvert Distilling Co., Clarion, Pa., as Chemical Engineer, having resigned his position as Chemist at Purdue University, Lafayette, Ind.

S. H. INGBERG, long-time A.S.T.M. member and Committee member, has retired as Principal Materials Engineer at the National Bureau of Standards.

MICHAEL KENT is now Textile Technician, American Institute of Laundering, New York City. He was previously associated with Manville Fabrics, Inc., in a similar capacity.

HERBERT S. SCHENKER, formerly Assistant Chief of Textiles, United Nations Relief and Rehabilitation Administration, Washington, D. C., is now Director for Supply, American Joint Distribution Committee, Paris, France.

WALTER EATON SPICER, JR., is now with the Lambert Pharmacal Co., Quality Control Div., Jersey City, N. J. He was formerly Assistant Sales Manager, Allied Home Products, Beloit, Wis.

E. E. THUM, Editor of *Metal Progress*, JOHN CHIPMAN, Professor of Metallurgy, Massachusetts Institute of Technology, H. J. FRENCH, Vice-President of the International Nickel Co., Inc., O. T. MARZKE, Supervisor, Naval Research Laboratory, and CYRIL S. SMITH, Chief of the Institute of Metals at the University of Chicago, have been appointed to form a metallurgical advisory committee to the National Bureau of Standards.

JOHN M. GROVE, of Lloyd's Register of Shipping, has been transferred from Baltimore to Pittsburgh where he will be surveyor for steel testing duties.

CASE SCHOOL OF APPLIED SCIENCE, Cleveland, Ohio, has changed its name to Case Institute of Technology.

ALAN GOLDBLATT, District Consultant for the Applied Research Laboratories of Glendale, Calif., has opened a spectrochemical testing and consulting laboratory, the Chicago Spectro Service Laboratory, Inc.

ALBERT D. KING, formerly associated with DeBell & Richardson, Springfield, Mass., has opened offices in Northampton, Mass., as Consulting Engineer.

NECROLOGY

EARLE W. MCMULLEN, Director of Research, The Eagle-Picher Co., Joplin, Mo. (August 26, 1947). A long-time member of the Society, his membership dating from 1916, Mr. McMullen had been interested in many A.S.T.M. activities and he contributed unstintingly of his energy and talents to the advancement of the Society's activities. At the time of his death he was affiliated with Committee D-1 on Paint Varnish, Lacquer, and Related Products and also Committee C-16 on Thermal Insulating Materials. He served as a member of the Board of Directors from 1943 to 1945. A native of Canada, he studied at Armour Institute of Technology, and later taught there. Before joining Eagle-Picher he was Director of Research at the Simmons Co. of Kenosha, Wis. One of his notable technical activities involved water emulsion paints. In his death the Society loses a most interested and active member, and his loss will be felt keenly by his many Society friends and associates.

POWELL PARDEE, New York district manager for the Inland Steel Company (September 9, 1947). A member of the Society since 1912, Mr. Pardee had been for almost twenty-five years a member of Committee A-1 on Steel. He had been affiliated with his company for almost forty years following his graduation from the University of Chicago.

RALPH A. CORLEY, President, The Corley Company (August 14, 1947). Mr. Corley had been active in the work of Committee A-7 on Malleable-Iron Castings since 1936 when he joined the Society. Mr. Corley's son, Robert N. Corley, has recently become a member of A.S.T.M.

D. E. WASHBURN, Chief Chemist, Warner Co., Bellefonte Div., Bellefonte, Pa. (September 20, 1947). Representative of Warner Co. membership and actively interested in Committee C-7 on Lime for many years.

ROY JABLONSKY, County Surveyor and ex-officio Highway Engineer, County of St. Louis, Clayton, Mo. (June 13, 1947). Member since 1944.

FRED F. SLACK, Chief Chemist, Corduroy Rubber Co., Grand Rapids, Mich. (July 23, 1947). Member since 1938 and active in Committee D-11 on Rubber and Rubber-Like Materials.

C. A. KELLOGG, Metallurgist, Continental Steel Corp., Kokomo, Ind. (June 2, 1947). Member since 1925 and active in Committee A-5 on Corrosion of Iron and Steel.

DAVID A. RUSSELL, Chief Chemist, The Youngstown Sheet and Tube Co., Youngstown, Ohio (July 26, 1947). Member since 1932 and Committee D-19 representative of Youngstown Sheet and Tube Co. since 1933, also personal member of Committee D-3 on Gaseous Fuels for many years.

C. R. PALMER, President, Palmer Thermometers, Inc., Norwood, Ohio. Representative of Company membership for many years.

JOHN TRAQUAIR, Director of Research, Mead Corp., Chillicothe, Ohio (July 19, 1947). Representative of TAPPI on Committee C-7 on Lime.

Society Appointments

ANNOUNCEMENT is made of the following appointments:

L. B. JONES, The Pennsylvania Railroad Co., on the Administrative Committee on Simulated Service Testing.

H. A. WAGNER, Detroit Edison Co., on ASA Sectional Committee B 16 on Pipe Flanges and Fittings, succeeding Sabin Crocker.

LARRY CRANSTON, United States Rubber Co., on ASA Sectional Committee L 3 on Specifications for Rubber-Lined Fire Hose, succeeding A. M. Finley.

R. R. LITEHISER, Ohio State Highway Testing and Research Laboratory, and H. S. MATTIMORE, Engineering Consultant, on ASA Sectional Committee A 1 on Cement. W. H. KLEIN continues as a representative and L. W. WALTER retires.

J. J. B. RUTHERFORD, Babcock & Wilcox Tube Co., on ASA Sectional Committee B 36 on Wrought Iron and Wrought Steel Pipe and Tubing.

JOHN WORTH, Bethlehem Steel Co., Inc., on ASA Sectional Committee B 18 on Bolt, Nut and Rivet Proportions, succeeding E. J. EDWARDS.

S. H. INGBERG, National Bureau of Standards, on ASA Sectional Committee A 2 on Specifications for Fire Tests of Materials and Construction, succeeding R. P. Miller, deceased.

WALKER REYNOLDS, Alabama Pipe Co., on ASA Sectional Committee A 4 on Standardization of Plumbing Equipment, succeeding J. D. STODDARD, with C. S. Cole replacing P. J. Smith as alternate.

LAURA E. PRATT, Sears, Roebuck & Co., on ASA Sectional Committee L 4 on Specifications and Standards for Sheets and Sheeting, succeeding W. H. WHITCOMB.

Belgium Engineers' Centenary

AN engineering Congress and Exhibition is being arranged by the University of Liege Association of Engineers to be held in Liege, Belgium from August 30 through September 13. A large number of papers will be presented in commemoration of the centenary of this organization. Headquarters of the group are located at 12, Quai Paul Van Hoegaerden, 12, Liege, Belgium.

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The British I.M.E. Proceedings

THE 1946 Proceedings of The British Institution of Mechanical Engineers has been received. This 500-page volume, 8½ by 11 in. page size, includes many technical papers and discussions, some undoubtedly of interest to members of A.S.T.M. A few of the items are noted here: Statistical Control in Workshop Administration, Notes of Design Stresses in Class 1 Welded Pressure Vessels, The Mechanism of the German Rocket Bomb, and Powder Metallurgy. Further information on the Proceedings can be procured from The Institution, Storey's Gate, St. James's Park, London, S.W.1.

Calendar of Society Meetings

AMERICAN SOCIETY OF TOOL ENGINEERS—Semi-Annual Meeting, October 30–November 1, Boston, Mass.

NATIONAL ELECTRONICS CONFERENCE—November 3–5, Chicago, Ill.

NATIONAL ELECTRIC MANUFACTURERS ASSOCIATION—International Lighting Exposition and Conference, November 3–7, Chicago, Ill.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS—Midwest General Meeting, November 3–7, Chicago, Ill.

SOCIETY OF AUTOMOTIVE ENGINEERS—Fuels and Lubricants, November 6, 7, The Mayo, Tulsa, Okla.

X-RAY AND ELECTRON DIFFRACTION—Annual Conference, November 7–8, Mellon Institute of Industrial Research, Pittsburgh, Pa.

FEDERATION OF PAINT AND VARNISH PRODUCTION CLUBS—November 7–10, Ambassador Hotel, Atlantic City, N. J.

PAINT INDUSTRY SHOW—November 7–14, Ambassador Hotel, Atlantic City, N. J.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION—25th Annual Convention, November 10–13, Roney Plaza Hotel, Miami Beach, Fla.

AMERICAN PETROLEUM INSTITUTE—Annual Meeting, November 10–13, Stevens Hotel, Chicago, Ill.

NATIONAL PAINT, VARNISH AND LACQUER ASSOCIATION.—November 11–14, Ambassador Hotel, Atlantic City, N. J.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA—Eighth Annual Water Conference, November 12–14, Hotel William Penn, Pittsburgh, Pa.

SOCIETY OF AUTOMOTIVE ENGINEERS—Air Transport, December 1–3, The Continental, Kansas City, Mo.

CHEMICAL INDUSTRIES EXPOSITION—Twenty-first Annual, December 1–5, New York, N. Y.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Annual Meeting, December 1–5, Chalfonte-Haddon Hall, Atlantic City, N.J.

HIGHWAY RESEARCH BOARD—27th Annual Meeting, December 2–5, National Academy of Sciences, Washington, D. C.

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS—December 4–6, Hotel Pennsylvania, New York, N. Y.

A.I.M.E. IRON AND STEEL DIVISION—Fifth Annual Conference, December 4–6, Electric Furnace Steel Committee, Hotel William Penn, Pittsburgh, Pa.

SCIENTIFIC APPARATUS MAKERS OF AMERICA—December 5–6, Hotel New Yorker, New York, N. Y.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS—1947 Winter Meeting, December 8–10, Hotel Traymore, Atlantic City, N. J.

AMERICAN CHEMICAL SOCIETY—Southwest Regional Meeting, December 12, 13, Houston, Tex.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE—114th meeting and International Science Exposition—December 26–31, Hotel Stevens, Chicago, Ill.

S.A.E. Annual Meeting—January 12–16, Book-Cadillac, Detroit, Mich.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS—Annual Meeting, January 27–30, Cleveland, Ohio.

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION—Winter Convention, March 14–18, Chicago, Ill.

AMERICAN SOCIETY OF TOOL ENGINEERS—16th Annual Meeting and Tool Exhibition, March 15–19, Cleveland, Ohio.

AMERICAN RAILWAY ENGINEERING ASSOCIATION—Annual Meeting, March 16–18, Palmer House, Chicago, Ill.

Proposed Method of Evaluation of Air-Entraining Admixtures for Concrete

Comments Solicited

AIR entrained in concrete by the use of admixtures, or additives to the cement, represents an outstanding development in concrete technology. Air, purposefully entrained and controlled in quantity, has been demonstrated to result in concrete with greatly improved resistance to such aggressive agencies as freezing and thawing, salts used to remove ice, alkali waters, etc. Additional advantages are greatly increased workability and decreased segregation. These benefits are accompanied, in general, by some reduction in strength but, with the quantity of air suitably controlled, the loss is relatively little and does not represent a sacrifice too great for the advantages gained.

A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates has prepared the accompanying method as a tentative basis for evaluating the merits of various admixtures which may be proposed for use. At this time the proposed method is published as information only. It is hoped that this will result in constructive criticisms and comments which will be helpful to the committee in revising the method with the view of recommending it as a standard. Comments should be directed to A.S.T.M. Headquarters. This work is under the jurisdiction of Subcommittee III-h on Methods of Testing and Specifications for Admixtures of which Bryant Mather is Chairman.

Proposed Method of Evaluation of Air-Entraining Admixtures for Concrete[1]

This is a proposed method and is published as information only. Comments are solicited and should be addressed to the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Scope

1. This method covers the procedure for the evaluation of materials proposed for use as air-entraining admixtures to be added to concrete mixtures in the field. The evaluation is based upon arbitrary stipulations permitting highly standardized testing in the laboratory and is not designed to simulate actual job conditions.

NOTE.—When it is desired to evaluate the admixture for use in specific work, the cement and aggregates used may be representative of those proposed for use and the concrete mixtures may be designed to have the cement content or contents specified for use in the work. In such cases, when the results of the evaluation are required in a period of time which will not permit curing of specimens for 180 and 365 days, the tests at those ages as required by Sections 7 (*a*) and (*b*) may be waived.

Materials

2. (*a*) *Cement.*—The cement used shall be a blend of three cements conforming to the requirements for Type I cements as prescribed in the Standard Specifications for Portland Cement (A.S.T.M. Designation: C 150).[2]

(*b*) *Aggregates.*—Fine and coarse aggregates used in any series of tests shall come from single lots of well-graded, sound materials conforming to the Standard Specifications for Concrete Aggregates (A.S.T.M. Designation: C 33),[3] except that the grading of the aggregates shall conform to the following requirements:

FINE AGGREGATE

SIEVE	PERCENTAGE PASSING
No. 4 (4760-micron)	100
No. 16 (1190-micron)	65 to 75
No. 50 (297-micron)	15 to 20
No. 100 (149-micron)	2 to 5

COARSE AGGREGATE

SIEVE	PERCENTAGE PASSING
1 in.	100
½ in.	50
No. 4 (4760-micron)	0

(*c*) *Preparation and Weighing.*—All materials shall be prepared and weighings shall be made as prescribed in Sections 2 and 3 of the Tentative Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Laboratory (A.S.T.M. Designation: C 192).[2]

Design of Concrete Mixtures

3. (*a*) Concrete mixtures shall be designed to have an actual cement content of 5.0 ± 0.05 bags per cu. yd. The water content of the mixtures shall be adjusted to provide a consistency equal to a 2½ ± ½-in. slump. The ratio of sand to total aggregate shall be adjusted to the optimum for concrete to be consolidated by hand rodding.

NOTE.—Recommended values[4] for the percentage of sand in the total aggregate by absolute volume are as follows:

	WITHOUT ENTRAINED AIR
Angular coarse aggregate	46
Rounded coarse aggregate	41

When an air-entraining admixture is used the values for percentage of sand may be reduced by approximately 4.

(*b*) *Conditions.*—Concrete mixtures shall be prepared both with and without the admixture under test and with an accepted air-entraining admixture (Note). The admixtures shall be added in an amount sufficient to produce 4.5 ± 0.5 per cent air in the concrete.

NOTE.—Until such materials have been designated by Committee C-9, the materials may be used which have been declared by Committee C-1 on Cement in the Tentative Specifications for Air-Entraining Portland Cement (A.S.T.M. Designation: C 175 T)[2] to be acceptable air-entraining additions to be interground with cement during manufacture. These materials are described as follows:

(*a*) A material known commercially as Vinsol resin, which is manufactured by the Hercules Powder Co. and consists substantially of the petroleum-hydrocarbon insoluble fraction of a coal-tar hydrocarbon extract of pine wood.

(*b*) A material known commercially as Darex AEA, which is manufactured by the Dewey and Almy Chemical Co. and is substantially a triethanolamine salt of a sulfonated hydrocarbon.

Mixing

4. Concrete shall be mixed in a revolving-drum mixer (Note) according to the provisions in Section 4 (*c*) of the Tenta-

[1] This proposed method is under the jurisdiction of the A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates. Published as information, October, 1947.

[2] 1947 Supplement to Book of A.S.T.M. Standards, Part II.

[3] 1946 Book of A.S.T.M. Standards, Part II.

[4] Values taken from Standard Recommended Practice for the Design of Concrete Mixes (ACI No. 613-44), *Journal*, Am. Concrete Inst., *Proceedings*, Vol. 41, Table 5, p. 656 (June, 1945).

tive Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Laboratory (A.S.T.M. Designation; C 192).[2] The concrete shall be mixed for 2 min. (after all materials have been added), allowed to rest in the mixer for 3 min., followed by 1-min. remixing.

NOTE.—The use of a 3.5-cu. ft. mixer with a batch size of 3.0 cu. ft. (solid volume) is recommended.

Tests on Plastic Concrete

5. Samples of the plastic concrete shall be tested in accordance with the following methods:

(*a*) *Consistency.*—Standard Method of Slump Test for Consistency of Portland-Cement Concrete (A.S.T.M. Designation: C 143).[3]

(*b*) *Unit Weight and Air Content.*—Standard Method of Test for Weight per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete (A.S.T.M. Designation: C 138).[3]

NOTE.—If, when tested according to this method, the air content of the concrete made without air-entraining admixture is more than 1.5 per cent, a different blend of three cements shall be prepared in accordance with Section 2 (*a*) so that the air content of such concrete will be 1.5 per cent or less.

(*c*) *Bleeding.*—The tendency of the concrete to bleed shall be determined in accordance with the Proposed A.S.T.M. Method of Test for Determination of Bleeding of Concrete.[5]

Test Specimens

6. (*a*) *Number.*—Three or more test specimens from each condition of concrete to be compared shall be made for each test and age. Specimens representing each test and each condition of concrete shall be made from at least three separate batches. An equal number of specimens for each variable should be made on any given day. When it is impossible to make at least one specimen for each variable on a given day, the mixing of the entire series of specimens shall be completed in as few days as possible and one of the mixes shall be repeated each day as a standard of comparison.

(*b*) *Types.*—The following types of specimens shall be made from concrete with and without the admixture under test for the tests indicated, except that beams for test of resistance to freezing and thawing shall be made from concrete with the admixture under test and from similar concrete containing an accepted air-entraining admixture:

(*1*) *Compression Tests.*—Compressive strength specimens shall be made and cured as specified in A.S.T.M. Method C 192.[2]

(*2*) *Flexure Tests.*—Flexural strength specimens shall be made according to A.S.T.M. Method C 192.[2]

(*3*) *Resistance to Freezing and Thawing.*—Test specimens shall consist of molded beams made in parallel from concrete containing the test admixture, and similar concrete containing an accepted admixture (see Note in Section 3 (*b*)). The specimens shall be not less than 3 nor more than 5 in. in width and depth and not less than 16 in. in length. The specimens shall be moist cured to an age of 14 days.

(*4*) *Bond-to-Steel.*—Specimens consisting of prisms of concrete containing axially embedded steel rods shall be prepared in accordance with the Proposed Method of Test for Determination of Strength of Bond of Concrete to Reinforcing Steel (Pull Out Test),[5] and moist-cured to an age of 28 days.

(*5*) *Length Change.*—Beam specimens shall be made in accordance with the Standard Method of Test for Volume Change of Cement Mortar and Concrete (A.S.T.M. Designation: C 157).[3]

Procedure

7. Specimens shall be tested in accordance with the following methods of the American Society for Testing Materials:

(*a*) *Compressive Strength.*—Standard Method of Test for Compressive Strength of Molded Concrete Cylinders (A.S.T.M. Designation: C 39),[3] tested at ages of 2, 7, 28, 180, and 365 days.

(*b*) *Flexural Strength.*—Standard Method of Test for Flexural Strength of Concrete (Laboratory Method Using Simple Beam With Third Point Loading) (A.S.T.M. Designation: C 78),[3] tested at ages of 2, 7, 28, 180, and 365 days.

(*c*) *Resistance to Freezing and Thawing.*—The specimens shall be subjected to alternate freezing and thawing while immersed in water. The freezing and thawing test shall be continued until the average dynamic modulus of elasticity E of the specimens in each group reaches 70 per cent of the E at zero cycles or until 200 cycles have been obtained, whichever occurs first. Determinations of dynamic modulus of elasticity shall be made in accordance with the Tentative Method of Test for Fundamental Transverse Frequency of Concrete Specimens for Computing Modulus of Elasticity (Sonic Method) (A.S.T.M. Designation: C 215).[2]

(*d*) *Bond-to-Steel.*—The strength of the bond between the concrete and the steel shall be determined in accordance with the Proposed Method of Test for Determination of Strength of Bond of Concrete to Reinforcing Steel (Pull Out Test).[5]

(*e*) *Length Change.*—Beam specimens shall be tested for shrinkage on drying in accordance with the Standard Method of Test for Volume Change of Cement Mortar and Concrete (A.S.T.M. Designation: C 157),[3] and the exposure and duration of the test shall be stipulated.

Criteria of Evaluation

8. An air-entraining admixture shall be considered to be acceptable if its effects on the properties of the concrete, determined as specified above, are as follows:

(*a*) *Bleeding.*—The percentage of bleeding by concrete containing the admixture under test shall not exceed 65 per cent of the bleeding of similar concrete without admixture.

(*b*) *Compressive Strength.*—The compressive strength of concrete containing the admixture under test shall be not less than 90 per cent of similar concrete without admixture at all ages.

(*c*) *Flexural Strength.*—The flexural strength of concrete containing the admixture under test shall be not less than 90 per cent of similar concrete without admixture at all test ages.

(*d*) *Resistance to Freezing and Thawing.*—The admixture under test will be considered as acceptable with respect to its effect on the resistance of concrete to freezing and thawing if the relative durability factor (RDF) (Note) is not less than 80.

NOTE.—*Relative Durability Factor (RDF).*—The relative durability factor shall be calculated in the following manner:

$$RDF = \frac{DF}{DF_1} \times 100$$

where:

DF = durability factor of the concrete containing the admixture under test, and

DF_1 = durability factor of concrete containing the acceptable reference admixture.

The values of DF and DF_1 shall be calculated, as follows:

$$DF \text{ (or } DF_1) = \frac{PN}{200}$$

where:

P = dynamic modulus of elasticity (e of 70 or more per cent of the E at zero cycles.

N = number of cycles at which P reaches 70 per cent or 200 if P does not reach 70 per cent prior to the end of the test (200 cycles).

(*e*) *Bond Strength.*—The bond strength at 28 days of concrete containing the admixture under test shall be not less than 90 per cent of similar concrete without admixture.

(*f*) *Length Change.*—The length change on drying of the concrete containing the admixture under test shall be not more than 110 per cent of that of similar concrete without admixture.

Report

9. The report of the evaluation of an air-entraining admixture shall include:

(*a*) Results of the tests as specified in Sections 5 and 7 as compared with the criteria given in Section 8,

(*b*) Brand names,

(*c*) Manufacturer's lot numbers,

(*d*) Quantities of the admixtures represented,

(*e*) Proportions in which the admixtures were used,

(*f*) Actual cement factors,

(*g*) Water-cement ratios, and

(*h*) Ratios of sand to total aggregate for the concrete batches made.

[5] In process of formulation by A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates.

Estimated Properties of Common Compositions of Hot-Rolled and Cold-Drawn Carbon-Steel Bars

By the Mechanical Property Group of Subcommittee XV on Bar Steels of A.S.T.M. Committee A-1 on Steel, composed of J. D. Armour, Republic Steel Corp., H. J. Cutler, Bethlehem Steel Co., J. H. Frye, Columbia Steel and Shafting Co., W. F. Hodges, General Electric Co., C. L. Kent, Jones and Laughlin Steel Corp., H. B. Knowlton, International Harvester Co., J. G. Morrow, Steel Co. of Canada, and J. R. Thompson, American Steel and Wire Co.

For many years, A.S.T.M. specifications A 107 and A 108 have been widely used by all types of purchasers requiring general purpose hot-rolled and cold-drawn carbon steel bars. In 1947 both specifications have been revised bringing them abreast of current steel bar compositions and qualities. In A 107, for instance, provisions have been made for both Merchant and Special Bar Qualities, while A 108, covering cold-finished material, permits only the application of Special Bar Quality which is standard for the cold-drawn industry.

Another change, which will become apparent to close observers, is the omission of appendices which gave estimated mechanical properties and general information on end uses.

Subcommittee XV, which has jurisdiction over these specifications, has felt for some time that the appendices were not altogether accurate and that it was desirable to assemble more complete information for the benefit of steel users. A subgroup was appointed to study the problem and this group, after a year's deliberation, has submitted the data shown in accompanying Tables I and II.

It was the consensus of the full membership of Subcommittee XV that information of this type, if properly used, constituted a valuable contribution to the users of both specifications. At the same time, since the American Society for Testing Materials is a specification-writing body, some members felt that the information might be subject to misinterpretation even though both specifications were clearly labeled to the effect that the appendices were for information purposes only and not binding on the steel producer. After considerable discussion, it was decided to publish the data and they are presented here as a matter of general information. The tables will not be published as a part of the specifications.

Hot-Rolled Bars

Several conditions should be observed in utilizing the tables. In Table I, for instance, the test figures are predicated on $\frac{3}{4}$-in. to $1\frac{1}{4}$-in. rounds tested full size. The cooling rate from the mill finishing temperature varies with the size so that smaller sizes will, in general, be finished colder and have higher tensile and yield point values than shown. Larger sizes will show progressively lower properties.

Since rolling mill finishing temperatures, speed of rolling, and conditions of the hot beds have a decided effect on the properties of untreated steels, steel mills are unable to supply hot-rolled steel to both chemical and mechanical requirements.

If mechanical properties must be maintained at a uniform level, the desired range should be specified and the chemistry will be varied by the producers according to mill experience, with higher carbon content being applied on the larger sections.

The experience listed in Table I also is based on negligible amounts of incidental alloys (nickel, chromium, molybdenum, and copper) being present in the steel. These elements, where present in small amounts, have a multiplying alloying effect and may appreciably affect the properties of carbon steels so contaminated.

Cold-Drawn Bars

The mechanical properties for cold-drawn steels shown in Table II are given as a *range* rather than *minimum* values as in Table I. In addition to the variables that affect the mechanical properties of hot-rolled bars, there are other factors which have a considerable bearing on the results obtained after cold drawing. The most important is that of bar size as compared to the draft or the percentage of cold reduction used in processing. Oftentimes—and it is generally true—a producer will use the same frac-

Editor's Note.—This article correlated for the A-1 Subcommittee XV group by E. V. Bennett, Bethlehem Steel Co., Secretary of the Subcommittee, should be of widespread interest to all those who use the two specifications involved. It is appropriate to point out that this very active subcommittee has in the past two years developed several purchase specifications which are filling a very definite need. It had become increasingly apparent that a serious gap existed in the specifications issued by the Society's Steel Committee in that there were no A.S.T.M. standards for the many different types and grades of so-called commercial bar steels, other than the standards A 108 (Cold-Finished Carbon-Steel Bars and Shafting), and A 107 (Hot-Rolled Carbon-Steel Bars), which essentially are based on chemical composition. A list of the specifications for which Subcommittee XV is now responsible follows:

A 107—Hot-Rolled Carbon-Steel Bars
A 108—Cold-Finished Carbon-Steel Bars and Shafting
A 286—Heat-Treated Alloy-Steel Bars
A 304—Alloy-Steel Rounds Suitable for Oil Quenching to End-Quench Hardenability Requirements
A 306—Medium Carbon Bars to Mechanical Property Requirements
Stress Relief Annealed Cold-Drawn Bars (in course of approval)

TABLE I.—APPLICABLE TO HOT-ROLLED CARBON STEEL BARS ORDERED TO A.S.T.M. SPECIFICATION A 107.

NOTE.—The tensile test values given in this table are calculated from a volume of test data reported by numerous steel mills. The basis used as to bar size was rounds ¾ to 1¼-in., tested full size in the as-rolled condition; therefore, due adjustments should be allowed for effects of mass in the case of larger or smaller sections. The tensile properties given are typical values and are not to be considered part of Specification A 107.

Type	Grade Designation	Estimated Values, psi., As Rolled		Cold Forming[a]	Forging[b]	Case Hardening[c]	Flame and Induction Hardening[d]	Welding[e]	Brazing		Heat-Treating (Quench and Temper)	Typical Applications
		Tensile Strength, minimum	Yield Point, minimum						(Furnace Process)	(Torch Method)		
Dead soft steels	1008	42 000	21 000	Good	Good	Fair	...	Good	Good	Good	...	Low strength assemblies requiring maximum in forming and welding properties
	1010	45 000	22 500	Good	Good	Fair	...	Good	Good	Good	...	
Soft steels	1015	50 000	25 000	Fair	Good	Good	...	Good	Good	Good	...	Used "as rolled" for many low strength parts made from forgings or bar stock not requiring much machining. Shafting, rolled thread bolts and screws. Used case hardened and heat treated for ratchets pins, rollers, shifter forks, etc. Used in numerous welded assemblies
	1016	56 000	28 000	Fair	Good	Good	...	Good	Good	Good	...	
	1020	56 000	28 000	Fair	Good	Good	...	Good	Good	Good	...	
	1022	63 000	31 500	Fair	Good	Good	...	Good	Good	Good	...	
	1025	60 000	30 000	Fair	Good	Good	...	Good	Good	Good	...	
	1030	68 000	34 000	Fair	Good	Good	...	Good	Good	Good	...	
Medium carbon	1035	73 000	36 500	...	Good	...	...	Fair	Good	Good	Good	Used "as rolled" for shafting, bolts, and studs. Used "as forged" for many medium strength parts. Higher strength obtainable by heat treatment
	1040	77 000	38 500	...	Good	...	...	Fair	Good	Good	Good	
Heat treating	1045	84 000	42 000	...	Good	...	Good	...	Fair	Fair	Good	"As rolled" or "as forged and annealed" for shafting and machine parts. Widely used for heat-treated parts and flame and induction hardening applications
	1050	93 000	51 500	...	Good	...	Good	...	Fair	Fair	Good	
High carbon	1055	96 000	53 000	...	Good	...	Good	...	...	...	Good	Used in heat-treated condition for battering tools, ground working tools, small springs, and wear-resisting applications
	1060	102 000	56 000	...	Good	...	Good	...	...	...	Good	
	1070	110 000	60 500	...	Good	...	Good	...	...	...	Good	
	1080	118 000	65 000	...	Good	...	...	...	...	...	Good	
Maximum hardness	1095	130 000	71 500	...	Good	...	...	...	...	...	Good	Edge tools, springs, parts requiring maximum hardness and wear resistance
Open-hearth screw steels	1115	57 000	28 500	...	Fair	Fair	...	...	Good	Good	...	Bar and forging applications where free machining is desirable. Parts made from these steels may be case hardened. Frequently used cold drawn
	1117	62 000	31 000	...	Fair	Good	...	...	Good	Good	...	
	1118	64 000	32 000	...	Fair	Good	...	...	Good	Good	...	
	1120	62 000	31 000	...	Fair	Fair	...	...	Good	Good	...	
Medium carbon free cutting	1137	87 000	48 000	...	Fair	...	...	...	Good	Good	Good	Free machining bars or forgings which may be heat treated
	1141	92 000	50 500	...	Fair	...	Good	...	Good	Good	Good	
	1151	93 000	51 000	...	Fair	...	Good	...	Good	Good	Good	
Soft bessemer	B1110	55 000	27 500	Fair	Fair	Fair	...	...	Good	Good	...	
Bessemer screw steels	B1111	60 000	30 000	...	...	Fair	...	...	Good	Good	...	Used where free machining and good finish on machined surfaces are of greatest importance. Widely used for machine parts not subjected to high stresses. Have low shock resistance and should not be used for applications involving shock loading. Usually used in Cold Finished conditions. Sometimes case hardened.[e]
	B1112	60 000	30 000	...	...	Fair	...	...	...	...	...	
	B1113	60 000	30 000	...	...	Fair	...	...	...	...	...	

[a] It is advisable to indicate type of application on the purchase order.
[b] When bars are intended for forging it should be so stated on the purchase order.
[c] For best results, orders should state that bars are to be used for case-hardened parts. Bessemer Screw Steels are not recommended for carburizing but are frequently case hardened by the molten cyanide process.
[d] Bars will not properly surface harden unless decarburized surface is removed by machining or grinding.
[e] For spot, seam and projection welding by the resistance method, steels higher in carbon content than grade 1020 are not recommended.

tional reduction over a wide range of bar sizes, and this means there would be a varying percentage of cold reduction. Thus, if a $\frac{1}{16}$-in. draft was used in drawing a $\frac{3}{4}$-in. round bar of a given analysis and the same draft used in cold drawing a 2-in. round, there would be a considerable difference in the percentage of cold work done on the two bars. This has a great bearing on the test results and for that reason it is impracticable to quote average mechanical properties. Since the size tolerances for cold-drawn bars are extremely close and those for hot-rolled bars are much wider, it also follows that this percentage of cold reduction can vary by the amount of variation in the exact size of the hot-rolled bars which are subsequently cold drawn.

The mechanical properties shown in the table are based on those generally found in sizes $\frac{1}{4}$-in. to 3-in. round that have had no previous or subsequent heat treatment, other than the annealing of the 1050 and 1095 grades prior to cold drawing.

The amount of reduction in cold drawing can be varied widely in most instances so that either lower or greater mechanical properties can usually be developed by the cold-finished steel bar producers. Upon application, it is often possible to secure required mechanical properties in bar form in this manner and thus avoid more costly heat treatment.

The cold work done upon the metal in the cold drawing operation increases the yield point or yield strength materially and the tensile strength to a somewhat lesser extent, with some decrease in elongation and reduction of area, so that there will be more "spring-back" in cold forming operations. When sharp bending, coining, blanking or other such cold operations are involved in fabrication, it is advisable to submit this information to the supplier, so that the material can be processed especially for the type of operation involved. When cold-drawn bars are heated much over 1200 F., the cold working strains are removed or equalized and the mechanical properties of the steel will more closely approach those of hot-rolled bars. Heating operations between 500 F. and 1200 F. will pro-

TABLE II.—APPLICABLE TO COLD-DRAWN BARS ORDERED TO A.S.T.M. SPECIFICATION A 108.

NOTE.—The mechanical properties listed below are given only as a matter of information and convenience. They do not form a part of Specification A 108 and are not to form a requirement of any specification or order unless each instance is approved by the sources of supply. These properties can generally be expected from cold-drawn bars in sizes ranging from ¼ to 3-in. diameter, inclusive. Values for turned and polished, turned and ground or other forms of cold finishing may differ widely from the above. Upon application to the sources of supply more exacting properties, or those of less or greater degree than those shown in the table, may be developed by varying the amount of cold reduction and/or in combination with thermal treatments.

Type	Grade Designation	Estimated Values Cold Drawn					Typical Applications
		Tensile Strength, psi.	Yield Point, psi.	Elongation in 2 in., per cent	Reduction of Area, per cent	Brinell Hardness	
Dead soft steels	1008	50 to 65 000	40 to 55 000	20 to 30	50 to 60	95 to 121	These grades produce steels of low hardness and maximum ductility. Suitable for cold forming, coining, severe bending and similar types of fabrication requiring high elongation
	1010	55 to 70 000	45 to 60 000	18 to 28	45 to 60	111 to 143	
Soft steels	1015	60 to 75 000	50 to 65 000	15 to 25	45 to 55	121 to 156	General purpose low carbon steels. Used extensively for shafting and cold heading applications. Grades 1015 to 1022, inclusive, widely used for carburizing. 1030 can be used for water quenching and tempering
	1016	65 to 80 000	55 to 70 000	15 to 25	45 to 55	131 to 167	
	1019	68 to 83 000	58 to 78 000	15 to 25	40 to 55	149 to 183	
	1020	68 to 83 000	55 to 70 000	15 to 25	40 to 50	149 to 183	
	1022	70 to 90 000	60 to 80 000	15 to 25	40 to 50	163 to 197	
	1025	70 to 90 000	60 to 80 000	15 to 25	35 to 45	163 to 197	
	1030	75 to 95 000	65 to 85 000	13 to 22	35 to 45	179 to 207	
Medium carbon	1035	80 to 100 000	70 to 90 000	12 to 20	35 to 45	179 to 217	Steels of increasing response to heat treatment. Can be either oil or water quenched
	1040	85 to 105 000	75 to 95 000	12 to 20	35 to 45	187 to 223	
Heat treating	1045	90 to 115 000	80 to 100 000	10 to 18	30 to 45	187 to 241	Usual grades of medium carbon general purpose steels recommended for oil quenching. Used for high strength shafting and treated machined parts
	1050[a]	90 to 115 000	80 to 100 000	10 to 20	30 to 45	201 to 235	
Maximum hardness	1095[a]	90 to 115 000	80 to 100 000	10 to 20	30 to 40	201 to 235	Steels requiring high hardness after heat treatment such as common spring steel
Open-hearth screw steels	1115	65 to 80 000	55 to 70 000	15 to 25	40 to 50	137 to 170	Low carbon free machining steels. Less machinable than Bessemer grades but possessing greater ductility and impact. Also used extensively for carburizing
	1117	70 to 85 000	60 to 75 000	15 to 25	40 to 50	149 to 183	
	1118	75 to 90 000	65 to 80 000	15 to 25	40 to 50	149 to 183	
Medium carbon free machining	1137	90 to 115 000	80 to 100 000	12 to 20	35 to 45	187 to 235	Medium carbon free machining grades. Suitable for induction heating and heat treating by oil quenching and tempering
	1141	95 to 120 000	85 to 105 000	10 to 20	35 to 45	197 to 248	
	1151	100 to 130 000	90 to 110 000	9 to 18	30 to 40	197 to 248	
Soft bessemer	B1110	65 to 80 000	55 to 70 000	15 to 25	40 to 50	149 to 183	General purpose soft steel. Possesses good bending properties but is not free machining
Bessemer screw steels	B1111	75 to 100 000	70 to 95 000	10 to 20	35 to 50	179 to 229	Used where maximum machinability and good finish are important. Not recommended for applications involving shock and fatigue nor for cold bending applications. Widely used in automatic machines
	B1112	75 to 100 000	70 to 95 000	10 to 20	35 to 50	179 to 229	
	B1113	75 to 100 000	70 to 95 000	10 to 20	35 to 50	179 to 229	

[a] Grades annealed prior to cold drawing.

duce a wide range of mechanical properties in cold-drawn steel, depending upon the temperature used and the amount of strain in the steel.

In addition to cold drawing, there are other types of cold finishing steel bars such as turning, grinding and polishing; turning and polishing; and cold drawing, grinding and polishing. The first two do not affect the mechanical properties of the steel and the resulting properties will be those of the hot-rolled bars. The values for cold-drawn, ground and polished steel bars will be the same as those for cold-drawn steel, since this material is first cold drawn and then more highly finished by grinding and polishing.

There are no notes in Table II relative to the suitability of the various grades for specific manufacturing operations. Cold-drawn bars are harder than hot-rolled material of the same composition and, in general, cold form less readily. All of the other operations mentioned in Table I (forging, case hardening, flame and induction hardening, welding, brazing and heat treating) involve heating operations where the superior mechanical properties and improved surface finish of cold-drawn bars are largely or entirely lost.

Catalogs and Literature Received

THE GAERTNER SCIENTIFIC CORP., 1201 Wrightwood Ave., Chicago 14, Ill. An eight-page bulletin entitled "A Survey of Precision Instruments" contains a complete list of the Gaertner standard products and services grouped according to their basic uses: linear, coordinate, angular, spectral, polarized light, photometric, optical test, and time measurements, optical parts, and special services. Illustrated.

Also, Bulletin 151-74, eight pages, 8½ by 11 in., describing "L254 Large Two-Lens Quartz Spectrograph." This spectrograph is recommended for applications requiring the highest quality spectra, the greatest quantitative precision, and the widest flexibility. Illustrated.

JARRELL-ASH CO., 165 Newbury St., Boston 16, Mass. JACO Catalog No. B5 covering "Standard Publications on Spectroscopy and Optics" includes general references on spectroscopy, emission spectroscopy, visible and ultraviolet absorption spectrophotometry, microscopy, X-ray diffraction, theoretical and applied optics, etc., 8½ by 11 in., 12 pages, illustrated.

E. MACHLETT & SON, 220 East 23rd St., New York 10, N. Y. Bulletin B-211 covering the Coleman Junior Spectrophotometer with the new Interchangeable Scales. This instrument is designed for the analytical laboratory where precision, reliability and convenience are important. 8½ by 11 in., 8 pages, illustrated. Also, Bulletin B-212 covering the Coleman Universal Spectrophotometer Model 14. 8½ by 11 in., 8 pages, illustrated.

HENRY A. GARDNER LABORATORY, INC. 4723 Elm St., Bethesda 14, Md. Four-page folder describing the Gardner Visco-Meter for rapidly measuring the viscosity of extremely viscous oils or similar products. Illustrated.

ENGINEERS SPECIALTIES DIVISION of The Universal Engraving and Colorplate Co., Inc., 980 Ellicott St., Buffalo 8, N. Y. A small pamphlet describing an optical projection comparator universally adaptable to all uses. Illustrated.

Digest of Articles on Diamonds

THE Industrial Diamond Information Bureau, Industrial Distributors (1946) Ltd., St. Andrew's House, 32–34, Holborn Viaduct, London, E.C.1, publishes monthly a bulletin containing abstracts of articles dealing with properties and industrial applications of diamonds, together with notices of patents and patent applications in many states. A copy of this bulletin may be obtained, free of charge, on application to the above address.

National Bureau of Standards

Several New Divisions Announced; Numerous Reorganization Moves; Divisions and Chiefs Listed

As a result of reorganization of its divisions and technical activities which at the same time has involved an expansion in some cases, there have been a number of new technical divisions established at the National Bureau of Standards in Washington. Some new divisions cover Building Technology, Atomic Physics, Applied Mathematics, and Commodity Standards. Within the past year or so a number of changes in personnel have occurred and all of these factors, it is believed, warrant an article which will give A.S.T.M. members a composite view of the Bureau.

Bureau and A.S.T.M. Work Closely

From the very nature of the Bureau's activities, with so many involving the field of materials, it is but logical to expect that much of the work done at the Bureau would be of interest to A.S.T.M. members on the one hand, and that, conversely, a great deal of the technical activity in A.S.T.M. would be of concern to the Bureau staff members. But it is still of interest to note that upwards of 100 of the Bureau's personnel are affiliated with A.S.T.M. and that these men and many others are taking a most active part in technical committee work. Several dozen committees are headed by NBS scientists. Three A.S.T.M. Past-Presidents have been at the Bureau, namely, Dr. George Burgess, a former Director of the Bureau, and Messrs. G. E. F. Lundell and P. H. Bates.

For those who wish to read an interesting article on current work at the Bureau, the address by the Bureau's current Director, Dr. E. U. Condon, given at the A.S.T.M. Headquarters Building Dedication Dinner in February, as published in the May ASTM Bulletin, is recommended. In this article Dr. Condon referred to the "close working relationship which has existed between A.S.T.M. and the Bureau," and in referring to the future of testing and technical work he prophesied that we would obtain a deeper insight into many of the perplexing problems of materials, based on new developments in atomic theory and new experimental techniques. He concluded: "The A.S.T.M. will play a great role in keeping abreast of these developments. We at the National Bureau of Standards shall try to do our part. Fundamentally the Bureau is a public service institution especially devoted to the needs of the engineering profession, and I hope that, working together, we can show much progress in the years ahead."

Purposes of Bureau

Created by an Act of Congress in 1901, the National Bureau of Standards is charged with the custody of the standards, comparison of those used in scientific investigations and in commerce, etc., with Government standards, and the testing and calibration of measuring equipment, determination of physical constants and properties of materials, and it has other responsibilities. The Bureau is considered the principal agency of the Federal Government for fundamental research in physics, chemistry, and engineering, the development of specifications for Federal Government supplies, and it is therefore intensely concerned with the work of the Federal Specifications Board which is headed by the Bureau's Director. It is of interest to note that in connection with its Research Associate Plan as many as 100 research associates have been stationed at the Bureau working on projects sponsored by various associations and groups.

Services for other Government agencies include the testing of supplies, materials, and equipment. A normal year's work includes the inspection of 5 to 8 million barrels of portland cement, 5 million electric lamps, chemical analysis of 6000 samples of paint, varnish, and bituminous materials, and life-testing of several thousand electric batteries. A mere list of the various materials tested would fill several pages.

The Bureau calibrates the base bars, geodetic tapes, theodolite circles, and airplane mapping lenses of organizations making accurate land surveys; it tests clinical thermometers of the Public Health Service and the Veteran's Administration, master beer meters of the Bureau of Internal Revenue, postal scales, postage meters and stamp vending machines for the Post Office Department; the work ranges from heavy equipment to precision laboratory items.

Some idea of the wide scope of the Bureau's work can be had from the list of scientific and technical divisions given below. Since it is not the purpose of this article to discuss in detail the work of each division because that would entail a rather voluminous article, the descriptions

E. C. Crittenden, Associate Director, left, and Dr. E. U. Condon, Director

of divisions are confined largely to new ones which have been recently established. Of the several new divisions established at the Bureau, two covering Building Technology and Commodity Standards respectively would be of very direct interest to large segments of the A.S.T.M. membership. But also of very specific interest would be the new Applied Mathematics Division and the Atomic Physics Division. Condensed descriptions of these divisions follow:

Building Technology

The Bureau has for many years been active in the field of building research. Through these years, certain sections, in various divisions, gradually developed into building research sections on particular phases of building technology—for example, the Fire Protection, Structural Engineering, and Heating and Air Conditioning Sections. The scope of this work has grown and the subject is of such national significance that the new Building Technology Division was created in order that a more integrated program could be pursued.

The forces and conditions to which buildings are subjected in everyday use will be studied and individual materials and assemblies will be investigated in order to determine their characteristics and the most effective ways in which they may be combined in the finished structure. Instead of establishing properties of materials and construction methods independently as in the past, a complete, coordinated program of investigations on each material or assembly will be pursued so that builders, designers, and owners can be provided with complete information. Some of the work will involve gathering together the mass of already existing information and coordinating it in the most useful manner. Unified scientific investigation in other fields of industry has been responsible for productive results, and it is reasonable to assume that the effect of this approach, when applied generally throughout the 10 billion dollar construction industry, can effect similar results.

The nucleus of the new division consists of five sections: structural engineering; fire protection; heating, ventilating and air conditioning; exterior and interior coverings; and codes and specifications. The structural engineering section will deal with the strength, stability, and stiffness of buildings and the structural elements of buildings. The fire protection section will continue its work on fire resistance of building construction, the fire hazard of building contents, and fire detecting and extinguishing equipment. Heating, ventilating and air-conditioning systems and heat transfer through materials and constructions will be the responsibility of the heating and air-conditioning section. The exterior and interior coverings section will handle roofing and waterproofing; floor, wall, and ceiling finishes for buildings; and in general the chemical and physical properties of bitumens. The codes and specifications section will carry on work formerly performed in another division on building, plumbing and safety codes and standards, building fixtures and service equipment and construction and maintenance practices.

Commodity Standards Division

This new division results from the consolidation of two divisions of the Bureau—Commercial Standards and Simplified Practice—into a single division. It will continue the Bureau's coordinating role in the development of voluntary simplified practice recommendations and commercial standards with industrial and technical groups. In addition, the division will be responsible for coordinating Bureau work for the Federal Specifications Board.

As the official standardizing agency of the Federal Government, the Bureau works in close cooperation with nonfederal agencies doing similar work. Thus at the present time the Bureau is represented on over 100 committees of the American Standards Association and is the managing agency for 17 American Standards Association projects. Similarly, the Bureau is represented on 55 of the 63 main technical committees of the American Society for Testing Materials, with more than 100 memberships, and close relations are maintained with other technical and industrial organizations.

The simplified practice program, initiated in 1921, is concerned with the elimination of uneconomical variety in a particular line of manufactured products. Commercial standardization, begun in 1927, is directed toward the development of voluntary standards for manufactured products. In the case of both activities, the National Bureau of Standards acts as a centralizing agency only, on request from industrial, commercial, or consumer gruops. Compliance with recommendations, which are approved by the groups concerned, is entirely voluntary.

An important addition to the division's functions will be the Federal Specifications work. Such specifications are vital in the purchase of goods by Federal agences because the bid system, used by the Government to ensure Federal economies in purchasing and to give an equal opportunity to all manufacturers under our competitive system of free enterprise, requires specifications for its operation. The division will also participate in the work of the Technical Committee of the United States Commodity Catalog Board which establishes standard lists of items for procurement and develops standard nomenclature and designation for goods purchased by the Federal Government.

Atomic Physics Division

Research in the field of atomic physics has been a part of the Bureau's work since 1913 when the first radium standards, prepared by Madame Curie,

F. B. Silsbee (Optics) | G. E. F. Lundell (Chemistry) | A. T. McPherson (Organic) | H. Insley (Mineral Products) | J. H. Curtiss (Mathematics)

W. Souder (Metrology) | J. G. Thompson (Metallurgy) | H. Diamond (Ordnance) | D. E. Parsons (Building Technology) | E. W. Ely (Commodity Standards)

entered into the custody of the Bureau. During the 1920's other projects, such as those on gamma radiation, were undertaken, and the study of electronic phenomena became an important phase of work at the Bureau. Because of its research activities, the Bureau was asked to initiate the atomic energy project shortly after word of the discovery of uranium fission reached this country in 1939. The Bureau continues to conduct research in this field for the Atomic Energy Commission.

The new Atomic Physics Division will conduct fundamental nuclear research, including studies necessary for the extension of measurement and standardization in this field. The effective realization of the possibilities of tracer techniques in chemistry, biochemistry, medicine, industrial process, and other areas now depends on the formulation of a great deal of basic information on radiation intensities, techniques of radiation measurement, instrumentation and calibration, and safety matters. Research has been started at the Bureau on the penetrating power of the beta radiation from a number of radioactive isotopes. A new method for tracing the isotopes through organic systems, called tracer micrography, has been developed which in preliminary testing has increased recognizable detail from 0.1 mm. to 30 μ, or 0.03 mm., with particular radioisotopes. A mass spectrometer specifically designed for the separation of atomic rather than molecular masses has been designed and is now under construction.

Applied Mathematics Laboratories

The new Division of Applied Mathematics will engage in basic research in this field and will in addition act as a service organization, particularly in the fields of engineering statistics and quality control, for the Bureau, the Armed Forces, other Governmental agencies, and industry. The division is organized in four sections: Numerical Analysis, Computation Laboratory, Statistical Engineering, and Calculating Machine Development.

The United States has, for some time, been the world leader in pure mathematics. Applied mathematics was "unfashionable" prior to the war. World War II threw into sharp focus the need for this branch of science. Urgent problems quickly arose in aircraft design, nuclear physics, radio design and propagation, explosion theory, gun-fire control, operational analysis, quality control in war plants, ballistics, and many other fields of endeavor. These problems led to the recruiting of an army of mathematicians, normally interested only in academic mathematics. With the end of the war most of these men returned to pure mathematics. However, the field of applied mathematics remains an indispensable tool in the newer and more technical industries. The division will be part of a plan to hold the gains already made and realize possibilities now opened up.

The division will utilize, particularly in its numerical analysis activities, the huge high-speed electronic digital computers, now under construction by the Bureau. Experts in the field believe that these new high-speed computers will revolutionize the field of applied mathematics. Until the advent of such machines as the ENIAC and the faster ones being built by the Bureau, a large part of the domain of applied mathematics was beyond the reach of the scientist. While solutions to complicated problems, such as the flutter analysis of aircraft wings, have been theoretically possible, the brute man-years involved in working out the equations has prevented the use of much of applied mathematics. It is estimated that a typical problem in the Census Bureau which now takes 12 days to solve will be completed with the new machines in less than 10 minutes.

The Office of Naval Research has been instrumental in establishing much of this program. At present O.N.R. is supporting the numerical analysis and computation groups and has contracted for an electronic computing machine.

The Statistical Engineering Section provides a general consulting service on the methods of modern statistical inference as applied to engineering and the physical sciences. It also provides training in the theory of statistics and formulates requirements for statistical tables and other aids in using the techniques. The Computation Laboratory, in which has been placed the Mathematical Tables Project, provides a general computing service of high quality and large capacity. The Machine Development Section is responsible for the design and construction of computing machines to meet the needs of various operating units.

Plans have been completed for the establishment of the Institute of Numerical Analysis at the University of California at Los Angeles. One of the giant high-speed electronic computing machines, now under development by the Bureau, will be installed at the Institute.

F. G. Brickwedde (Heat and Power) | J. H. Dellinger (Radio Propagation) | W. Ramberg (Mechanics)

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Errors in Our Thinking

A MOST interesting article by Sumner H. Slichter, Lamont University Professor at Harvard University and chairman of the research advisory board of the Committee for Economic Development, was published in *The New York Times Magazine* of August 10. The article entitled "Eight Errors in our Economic Thinking" gives as Number 1 Error: "Failure to appreciate the enormous dynamic possibilities of the American economy and its capacity to produce new enterprises and new industries."

The article continues: "Evidence of the tremendous dynamic drive of our economy is found in the rapid rise of industrial research. For more than seventy years the number of physicists, chemists, engineers, and metallurgists have been increasing from ten to fourteen times as fast as the gainfully employed. Expenditures on industrial research in 1939 were nine times as large as in 1920. The war has given a strong impetus to research, and research will expand during the next ten years faster than ever. Research is contagious because if one concern does it its competitors must do so also or be left behind.

"Research tends to make the economy more competitive, and competition is a powerful dynamic influence. Consider the ways in which industrial research has been broadening the range of competition during the last century. In the field of metals, steel has become cheap and has driven iron out of many uses. More recently aluminum has become a competitor of steel. Plastics and plywood are challenging metals at many points. Forging and welding have become competitors of molding.

"Railroads drove most of the canals out of business, and they, in turn, are meeting competition from automobiles, trucks, buses, and planes. Over a century ago cotton became a formidable competitor of woolens and linens. More recently the rayons and nylons have entered the competition. At many points cloth is meeting stiff competition from paper. Oil and natural gas challenge coal, steam drives out water power; the development of electrical equipment gives water power a partial comeback. Diesel engines become competitors of both steam and water power. Soon all of these forms of power production must meet the challenge of atomic energy.

"Before the war the country increased output per worker about 3 per cent a year. During the next decade or so the output should grow faster than before the war—by at least 4 per cent a year. In that case the annual income of the country between 1956 and 1960 should average, not $237 billion, but above $260 billion..."

The Technology of Adhesives

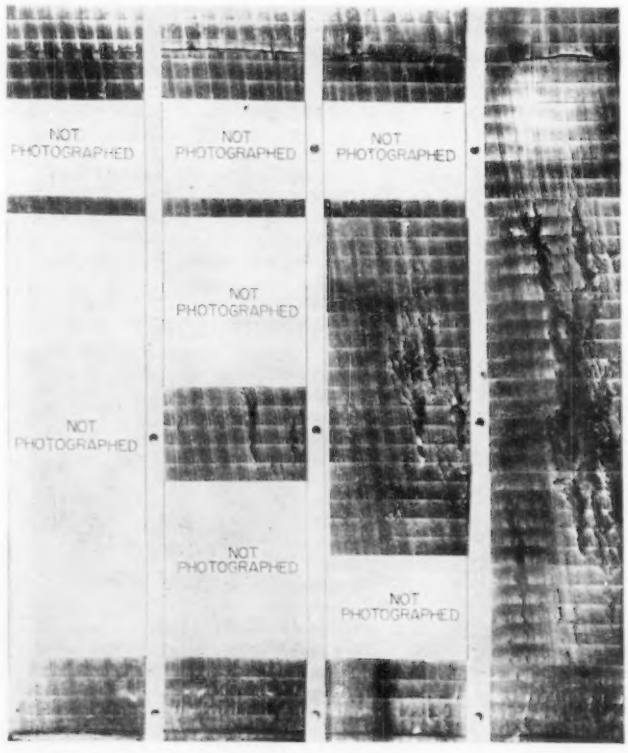
WITHIN a period of approximately ten years, the lowly and rather homely term of "glue," as applied to materials used for their adhesive properties, has blossomed forth and taken on the cloak of social respectability by assuming the more dignified and technical term of "adhesive." In this higher strata we also now find an intimate associate, namely, the term "high polymer." This rise to recognition, however, has been a struggle to keep from being overshadowed and absorbed by the magical and colorful term "plastics." This change is indicative of a lot more than the mere change in terms, as it marks a development that has been going at a fast pace, accelerated especially by the advent of the synthetic resin materials. We now talk in terms of urea-formaldehyde, phenolic and furane resin adhesives, along with a growing group of other base adhesive materials which, by the way, still include the animal glues of old—although now in a much more refined state.

The author, John Delmonte, Technical Director, Plastics Industries Technical Institute, has attempted to give a very comprehensive treatise on the growing, as well as maturing, family of adhesives. In fact, the author has dignified the field by calling it an industrial science. All those who are in contact or intimately associated with this field no doubt will agree to the justification of the title of technology—or science—of adhesives.

In the introductory chapter concise and interesting sections are given over to historical background, basic definitions and production data together with descriptions of chemical classifications, thermosetting and thermoplastic synthetic resin adhesives, naturally occurring polymers and solvent effect on adhesives. The chapter closes with sections on physical classification of adhesives and miscellaneous methods of classifying them.

The major portion of the book is devoted, first, to a series of chapters covering the entire gamut of adhesives including, among others, the phenolic, urea, polyvinyl, polystyrene resins, the cellulose derivatives, the sodium silicates, and the animal and vegetable glues. The second series of chapters furnishes detailed information and data on adhesives for use with specific materials such as wood; organic plastics; metal and rubber; papers, cloths and associated materials; and for inorganic materials, in turn.

The author has recognized, in the final chapter, that a more organized and coordinated effort has been under way to reduce the problems of adhesives to basic methods of evaluation, citing A.S.T.M. Committee D-14 on Adhesives as a major proponent of this attempt to establish test methods. In the descriptions of testing methods, several specifications and test methods developed by A.S.T.M., Forest Products Laboratory, and the Army-Navy Aeronautical Group are given. This book is available at $8 per copy from Reinhold Publishing Corp., 330 W. 42nd St., New York, N. Y.



"Boroscope Pictures of Interior of a Machine Gun Barrel at Various Stages of Its Life, Approx. X1.4."

Second prize-winning photograph, semi-micro-section, in the Fifth A.S.T.M. Photographic Exhibit, by Stanley Pennypacker, Frankford Arsenal.

Erosive Effects of Gun Blast on Materials—Development of a Strong Brittle Alloy*

By James A. Broadston[1]

THE current increase in the development of jet and rocket propelled craft has brought a proportionate rise of interest in materials resistant to the erosive effects of rapidly moving, combustible gases burning at high temperatures with explosive violence. Although much research is now in progress leading toward the development of heat- and erosion-resistant materials for housing such power units, this study came about as a result of the increased aircraft speeds made possible by such units.

There was a time when the barrels of machine guns on military aircraft could project out into the air stream with impunity. Improvements in the design of aircraft gradually brought higher and higher speeds until it became necessary to withdraw the guns into positions completely "submerged" within the mold line or skin line of the craft. This necessitated the use of gun blast tubes which extend forward of the gun barrel muzzle to an open port in the skin. These blast tubes allowed the guns to be fired without damaging the airplane as they provided a reinforced corrosion-resistant steel passage for the projectile as well as for the incandescent explosive gases which are expelled from the muzzle with each shot.

Progress in One Field Increases Problems in Another

The adoption of jet propulsion for piloted aircraft, with the consequent increase in speeds that approach and will probably soon exceed the speed of sound, has made it imperative that drag be reduced to a minimum. Open gun ports cause excessive drag and shock waves at these high speeds and cannot be tolerated if maximum performance is to be realized.

One solution that appeared to hold promise for overcoming this drag was the adoption of gun-port doors fitted to the gun-blast tubes and arranged to open quickly a fraction of a second before the guns start to fire and close immediately after each burst has been completed. When these doors are closed they conform to the exact airplane skin contour and provide a smooth surface that is almost perfect aerodynamically.

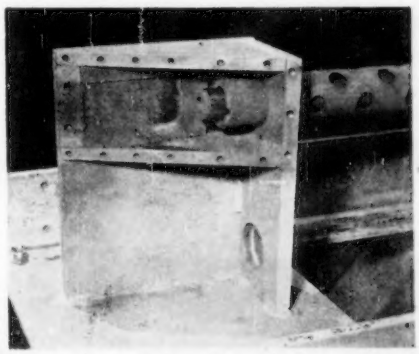


Fig. 1.—View of Gun-Blast Erosion Test Jig.

From a material standpoint such doors are quite difficult to design since they must not only be strong and ductile enough when in the open position to withstand the sharp repetitive impact, the heat, and the erosion of the explosive gases at the gun muzzle but will also (in the event of a malfunction of the door mechanism or inadvertent firing of the gun because of excessive barrel heat) allow themselves, when closed, to be shot off without damage to the craft.

Design Success Dependent upon Proper Material

A successful design was, in this instance, dependent upon finding or developing a material that had the desired properties. Without such a material the accomplishment of the task would have been impossible. The tests described in this paper are but a few representative ones of many that led to the development of the strong brittle high-copper-magnesium-aluminum alloy that was found satisfactory for this special application.

The tests were conducted at the engineering gun-firing range of North American Aviation, Inc., for the purpose of determining the effects of gun-blast gases on various commercial materials in an attempt to find one that would have the desired properties.

Early doors designed for the purpose were made of corrosion-resistant steel, but it was found that if they were made heavy enough to stand the heat and impact of the blast they would fly off in one or two large pieces when struck by the bullet and could easily damage the airplane by striking it or by being carried into the jet engine inlet. The

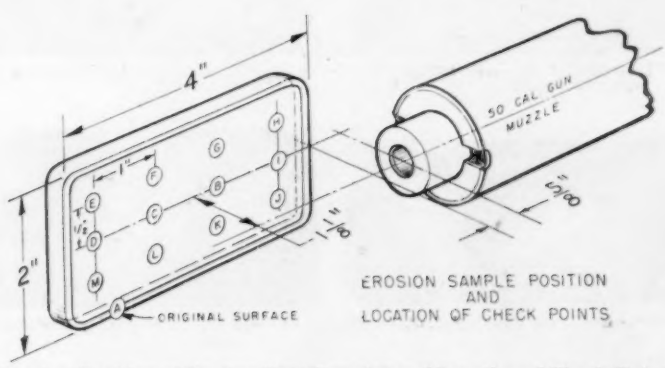
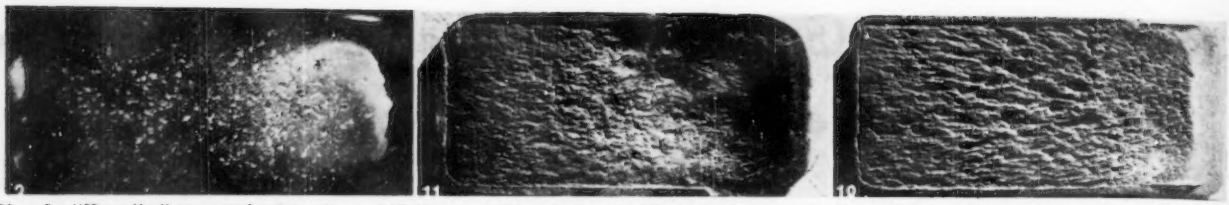


Fig. 2.—Position of Erosion Test Samples and Location of Check Points.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

* Presented at the Fiftieth Annual Meeting, Am. Soc. Testing Mats., Atlantic City, N. J., June 16–20, 1947.

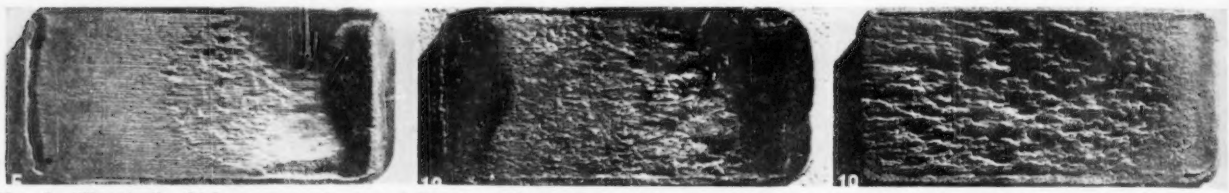
[1] Armament Design Engineer, North American Aviation, Inc., Los Angeles, Calif.



No. 3—"Herculite" tempered plate glass, 357 rounds.

No. 11—"Fiberglas" mat, "Laminac," low pressure, 141 rounds.

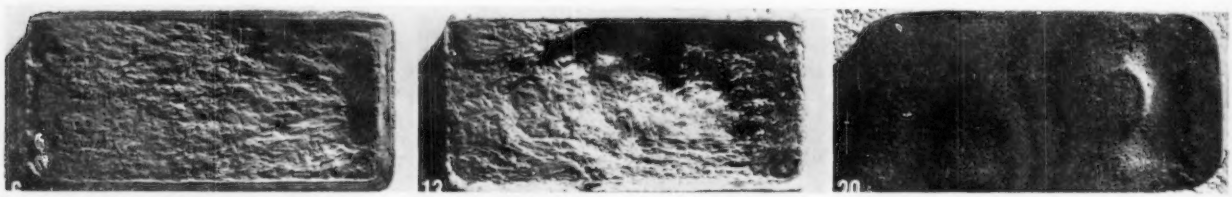
No. 18—Soft carbon-graphite block, 109 rounds.



No. 5—"Formica" high-pressure laminated phenolic, 281 rounds.

No. 12—"Fiberglas" mat, "Laminac," low pressure, 61 rounds.

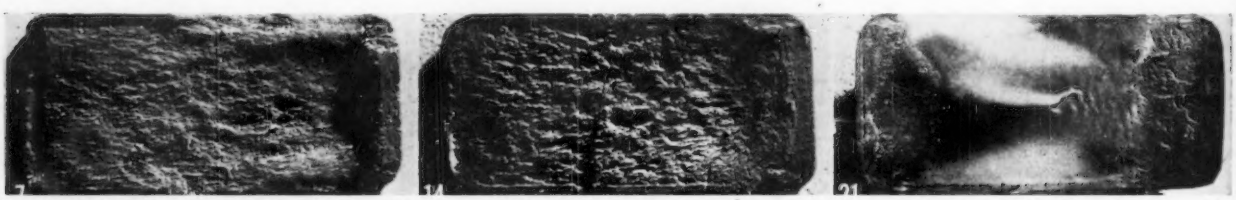
No. 19—Carbon block, chromium plated, 63 rounds.



No. 6—"Masonite" die stock, 150 rounds.

No. 13—"Fiberglas" mat, "Laminac," low pressure, 150 rounds.

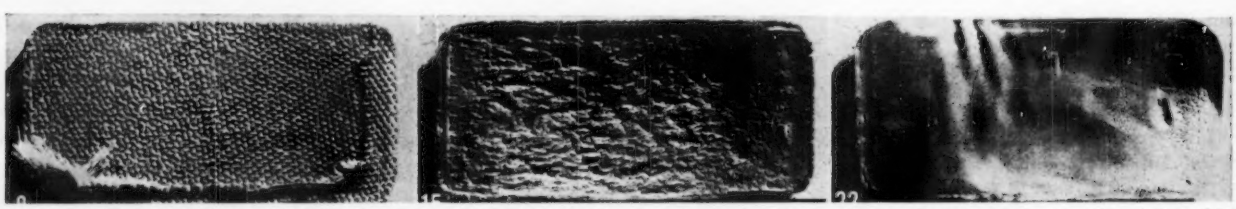
No. 20—Magnesium alloy sheet, 1/16 in. thick, 72 rounds.



No 7—"Johns-Manville" brake lining, 297 rounds.

No. 14—"Transite" commercial asbestos sheet, 336 rounds.

No. 21—Corrosion-resistant steel, 0.010 in. thick, 1020 rounds.



No. 8—"Fiberglas" cloth bonded with "Laminac," 37 rounds.

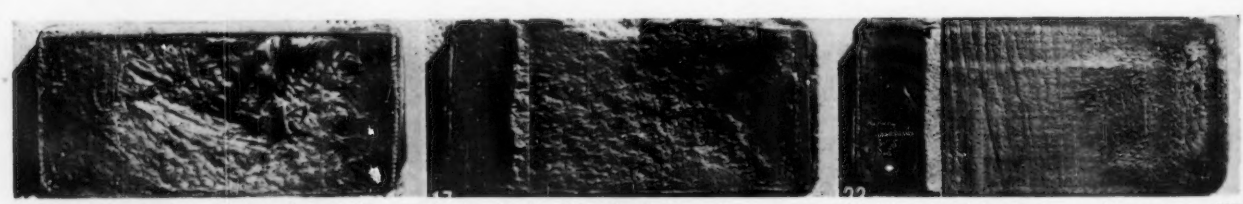
No. 15—"Transite" commercial asbestos sheet, 307 rounds.

No. 22—Corrosion-resistant steel, 0.010 in. thick, 150 rounds.

No. 9—"Fiberglas" mat, cloth facing, "Laminac," 60 rounds.

No. 16—G. E. "Texolite" molded part, 219 rounds.

No. 22(*a*)—Phenolic backing for steel sheet, 150 rounds.



No. 10—"Fiberglas" mat, cloth facing, "Laminac," 60 rounds.

No. 17—G. E. "Mycalex" glass-mica composition, 758 rounds.

No. 23—Frangible aluminum alloy casting, 2520 rounds.

Fig. 3.—Erosive Effects of Gun Blast on Various Commercial Materials.

TABLE I.—EROSION OF VARIOUS MATERIALS DUE TO GUN BLAST AND DETERMINATION OF EROSION FACTOR.

Sample	Material	Rounds	Erosion Factor[a]	Erosion at Points Shown in Fig. 2, thousandths in.[b]												
				A	B	C	D	E	F	G	H	I	J	K	L	M	Max.
No. 1	White glazed bathroom tile	8	....	Negligible													
No. 2	Ordinary plate glass, ¼ in.	81	....	Negligible													
No. 3	"Herculite" tempered plate glass	357	....	Negligible													
No. 4	"Tuf-Flex" tempered plate glass	154	....	Negligible													
No. 5	"Formica" laminated phenolic	281	0.378	0	72	12	0	0	10	48	52	67	64	52	12	0	*109*
No. 6	"Masonite" die stock	150	0.393	0	42	14	1	1	9	41	29	54	32	29	7	0	*59*
No. 7	"Johns-Manville" brake lining	297	0.404	0	96	43	5	5	30	80	55	100	75	105	25	0	*120*
No. 8	"Fiberglas" cloth laminate	37	0.540	0	18	15	8	10	16	17	20	20	*20*	19	13	10	...
No. 9	"Fiberglas" mat laminate No. 1 with glass cloth facing	60	0.567	0	15	5	5	3	3	10	20	*34*	28	18	7	5	...
No. 10	"Fiberglas" mat laminate No. 4 with glass cloth facing	60	0.467	0	25	25	8	9	13	17	13	20	10	*28*	18	10	...
No. 11	"Fiberglas" mat laminate	141	0.595	0	74	23	1	4	14	54	54	69	51	56	14	0	*84*
No. 12	"Fiberglas" mat laminate	61	0.525	0	20	5	0	0	2	13	19	*32*	22	18	5	0	...
No. 13	"Fiberglas" mat laminate	150	0.807	0	*121*	65	19	0	61	71	54	69	61	107	21	9	...
No. 14	3/16-in. "Transite"	336	0.065	0	*22*	22	7	10	15	16	2	7	2	0	22	12	...
No. 15	¼-in. "Transite"	307	0.163	0	35	45	9	5	20	22	5	2	0	38	*50*	10	...
No. 16	G. E. molded "Texolite"	219	....	Negligible—irregular thickness													
No. 17	G. E. "Mycalex" sheet (2821)	758	0.046	0	*35*	24	11	11	15	23	6	10	9	27	20	11	...
No. 18	Soft carbon block	109	0.587	0	*64*	33	10	17	19	32	4	0	6	44	24	14	...
No. 19	Chromium-plated carbon block	63	1.26	0	*80*	63	10	11	35	15	0	2	0	40	50	7	...
No. 20	1/16-in. magnesium sheet	72	....	Negligible—roughened surface													
No. 21	0.010 stainless-steel backing	1020	....	Negligible—smooth but wavy surface													
No. 22	0.010 stainless-phenolic backing	150	....	Negligible—smooth—heat burned backing													
No. 23	Brittle aluminum alloy	2520	0.0028	0	6	4	x	x	5	4	0	1	0	7	6	x	...

[a] Depth of maximum erosion in thousandths in. divided by number of rounds.
[b] Maximum values talicized.

material must therefore, when struck by a bullet, be brittle enough to shatter into hundreds of small pieces harmless to the aircraft. A further requirement is that the bullet itself, in such a case, should not be adversely deflected by the door material and ricochet back into the aircraft structure, but should be forced outward where it can do no harm. The material selected must be serviceable, dependable, allow easy fabrication, and resist the corrosive effects of the atmosphere when covered with the residue from firing.

Frangible Door Insert Proposed

It was first thought possible that a frangible door insert that could be "shot out" of the door frame in the event of accidental firing would solve the problem. Accordingly, a number of materials that appeared at that time to hold promise, were mounted in a jig as shown in Fig. 1. This jig held the samples in the same position relative to the 0.50 caliber gun muzzle as they would lie if they were mounted in the gun-port door.

The erosive effects of the gun blast on these materials are tabulated in Table I from measurements made at the points shown in Fig. 2 by means of a dial indicator having a 3/16-in. diameter stem with a 3/16-in. radius end.

All of the blast-erosion test specimens shown in Fig. 3 were tested in the jig shown except for the tempered plate glass specimen 3, which, since it could not be cut to size, was, like the other plate glass samples, mounted in a similar jig that would accommodate it and allow only a limited area to be exposed to the blast. Figure 4 shows the heavy black coating of gun-blast residue deposited on the glass after firing 357 rounds. This deposit was removed by using nitric acid prior to making the photograph of specimen 3 of Fig. 3.

At first it was believed that a brittle ceramic material might prove satisfactory as a door insert and a piece of glazed tile was mounted in the jig and exposed to the blast to see whether it would stand up under the blast impact and erosion. After a few shots it cracked.

Since the tile at hand was relatively soft, plate glass was selected as being equivalent to a hard ceramic. It took the blast better but after 81 shots a crack appeared. The abrasion was very slight. The next step appeared to be to try tempered plate glass. Several samples were tried and they stood the blast remarkably well. Sample 3 of Fig. 3 shows the "sand blast" effect and the chipping due to the blast impact on tempered plate glass. In this view an oblique light is cast on the surface and the sample is viewed through to a black background. It is interesting to note that although tempered plate glass normally breaks into small pieces immediately upon being chipped, this sample was extensively damaged by the blast and was still in good condition many months after the test. It is probable that the heat and high pressure of the

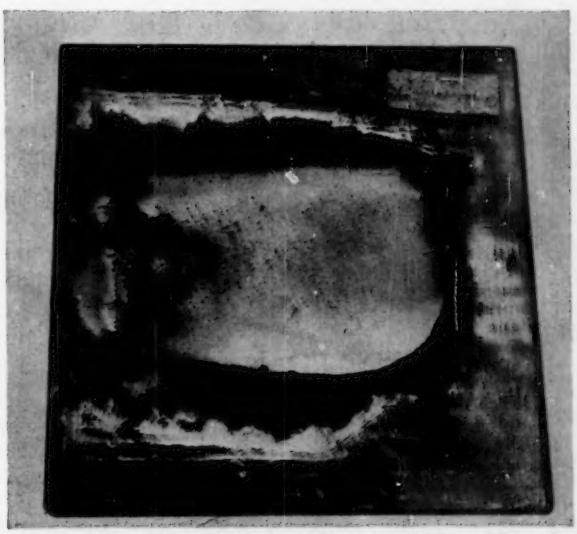


Fig. 4.—View of Gun-Blast Deposit on Tempered Plate Glass Specimen.

blast caused compression failures in the surface and transferred the outer compressed layer deeper into the plate, thus maintaining the balance of internal strain existing in this material. None of the glass samples exhibited enough erosion to obtain a dial indicator reading. During all of the tests with brittle materials a relatively soft pad of asbestos sheet was used to back up the sample. The heat of the blast apparently did not hurt the glass samples at all.

Surface Temperature 900 F.

Thermocouples mounted closely adjacent to the surface of a metal door indicated that temperatures as high as 900 F. might be expected. Experience with the glass, which was not even warm to the touch after a long burst of about 150 shots, led to the belief that if a dense nonconducting substance such as a high-pressure laminated phenolic were used it might be satisfactory. A sheet of "Formica" No. CJP-11 was mounted and after firing 281 rounds (shots) it appeared as shown in Fig. 3, sample 5. The blast heat seemed to soften the surface, allowing the intense pressure of the explosive gas mixture to penetrate and effectively delaminate the material. It is interesting to note that on this and other samples the severe vortices caused by the rapid passage of the blast gases past the jig plate edges (which extended only $\frac{1}{8}$ in. beyond the specimens) caused secondary erosion of some magnitude at the left of each sample.

Two substances, samples 6 and 7, were selected as being dense heat-resisting materials. Both, however, showed severe erosion with a nominal amount of firing and would therefore be quite inadequate to stand up under 10,000 rounds of fire which is required of such equipment for acceptance by the services. It should be noted that these explosive blasts make the internal fiber structure of a material quite visible and show up characteristic differences between materials.

Fiberglas Laminates Tried:

Since laminated phenolics would not stand up under the combined effects of the heat and blast, several specimens were made by laminating "Fiberglas" cloth and mat with a "Laminac" resin specially compounded for heat resistance. In sample 8 the blast heat burned the binder and the gases penetrated quickly beneath the cloth layers, exploded, and successfully delaminated them.

A glass fiber mat laminate covered with a very fine glass cloth surface layer was tried on samples 9 and 10 without appreciable improvement.

"Fiberglas" mat samples having a specially compounded filler using 30 per cent by weight of antimony trioxide and the "Laminac" binder in order to improve the heat resistance were tried in samples 11 and 12 without success. It should be realized that all of the "Fiberglas" laminates were low-pressure laminates. It is possible that if high molding pressures were used, a more dense product would result. Facilities were not available to make such samples easily.

Further search for commercially available dense heat-resisting materials that might serve resulted in trials with "Transite" and General Electric molded "Texolite" and "Mycalex."

The Transite samples 14 and 15 showed up remarkably well considering the severe heat and weathering effects of the gun blast. Slight hairline surface cracking was apparent after a few rounds. Erosion progressed more rapidly on longer bursts. Breakages shown occurred after the completion of the tests except for sample 15 which "caved in" due to blast pressure. It was $\frac{1}{4}$ in. thick and was supported at rear by a $\frac{3}{16}$-in. wide rim gasket.

Erosion Primarily Due to Porosity

As all nonconducting specimens appeared to absorb very little heat from the hot blast gas, since they felt only warm to the hand after a thirty-round burst, it appears that the erosion is due largely to porosity which allows unburned gas to penetrate and explode, causing small pieces of the material to be literally "blown off."

Except for the brittleness of the molded "Texolite" sample 16, which broke while being mounted (large irregular crack down center of specimen), it showed very good resistance to the blast erosion. The radial "cracks" are due to the action of surface erosion only, as they do not penetrate deeply.

Of all the commercial materials tested, sample 17, a two-piece "Mycalex" specimen, showed the least damage. The heat of the blast did not appear to damage this glass-mica composition even during 150 round bursts. Its $\frac{3}{8}$-in. thickness with a narrow rim supporting gasket withstood the blast quite well, but its slightly porous surface permitted gas penetration with subsequent erosion. It appears that any substance suitable for this application must be relatively nonporous.

Although hindsight does not justify it, the suggestion was made that a carbon block sealed by a thin closely adherent layer of chromium might prove satisfactory, since it was known that carbon would easily stand the heat and yet was brittle enough to shatter upon bullet impact.

Sample 18 shows the effect of the blast on an untreated block, while sample 19 was chromium plated. It is obvious now that, if anything, the chromium coating hastened the erosion by pulling off pieces of carbon immediately. Note that the untreated block was exposed to the blast from 109 rounds and the plated block to the blast from only 63 rounds. It should be noted that in some areas where the blast impact was not so severe, the plating did give a measure of protection, as may be seen by observing the difference in the erosion at the right-hand corners of the specimens. The erosion per round, as expressed by the "Erosion Factor" explained later, is about twice as much in the other areas as shown in Table I.

Gun Blast Like Sand Blast

Although magnesium sheet would not be a suitable door material because it will corrode so easily, sample 20 was tested to determine the abrasive effect of the blast upon a relatively soft nonporous surface. Except for the areas upon which a heavy deposit of carbon lies, the surface of the magnesium sheet is more severely roughened

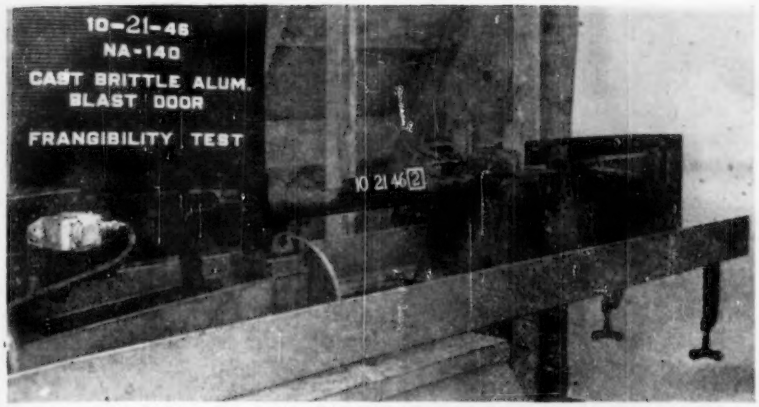


Fig. 5.—0.50 Caliber Gun with Blast-Tube Door Housing Mounted for Test.

than if it were sandblasted. The embossed circular area was caused by an "experimenter" who wanted to see whether the blast pressure on the 0.062-gage magnesium sheet would cause it to flow into the engraved surface of a dime. It did take some of the impression.

Since nonconductors in general throughout these tests absorbed so little heat, it was thought possible to coat a molded heat-resistant door with a thin skin of corrosion-resistant steel and effectively seal the surface against gas penetration. Sample 22, of 0.010-gage corrosion-resistant steel facing, deformed because of the blast heat and became so hot that it scorched the laminated phenolic block 22(*a*) which was used to back it up.

In view of the fact that corrosion-resistant steel has shown such remarkable resistance to the abrasive and corrosive effects of the blast gases, sample 21 was exposed to many long bursts to determine whether it would burn through. Except for wrinkling due to the heat and rubbing action of the blast it sustained no significant diminution in thickness. A heavy blast deposit remained after firing 1080 rounds.

Frangibility Also a Factor in Design

Concurrent with the erosion tests described above, these materials were also investigated to determine their frangibility when struck obliquely at a flat angle of about 10 deg. by a 0.50 caliber (0.500-in. diameter) bullet traveling at a velocity of 2660 ft. per sec. (1800 mph.). In these tests the frangibility of the material as well as its tendency to "seize" or "grab" the bullet and deflect it in the wrong direction was important to the investigation. None of the aforementioned materials was satisfactory from this standpoint, and data on these tests were not considered of sufficient general interest to A.S.T.M. members to include in this paper. The results, however, led to the development of a frangible alloy which is described later.

A sample of this special alloy was mounted in the erosion test jig and is designated in Fig. 3 as sample 23. Although 2520 rounds were fired, the surface is in relatively fine condition compared to any of the other samples shown. The block to the left was a piece of 24S-T aluminum alloy bar stock of greater thickness used as a filler. Note the severe erosion at the edge caused by the blast gases.

It is also interesting to note the unusual details of the erosive action on the slab-milled surface of sample 23. It appears that the projecting edges of the alloy are softened by the heat and are "rolled up" by the passage of the high-velocity gases over the surface. Close examination seems to indicate that as the copper matrix between the aluminum-magnesium alloy crystals is heated it becomes a ductile web that is pulled into the vertical ridges shown and leaves deep V-grooves behind. Note also the gun-blast deposit at the right of the specimen.

An Erosion Factor Permits Comparison

Reference to Table I will give an approximate index to the erosion of each of the samples described. An arbitrary comparison is made by determining an "erosion factor" which is equal to the maximum measured depth of the eroded surface as compared with the initial surface (expressed in 0.001 in.) divided by the number of rounds fired. Comparison of these values also shows the superiority of the brittle aluminum alloy in resisting gun-blast erosion.

Figures 5, 6, and 7 are included merely to show the general configuration of the gun-blast doors described and to illustrate the frangibility of the door material by showing how it breaks up after bullet impact.

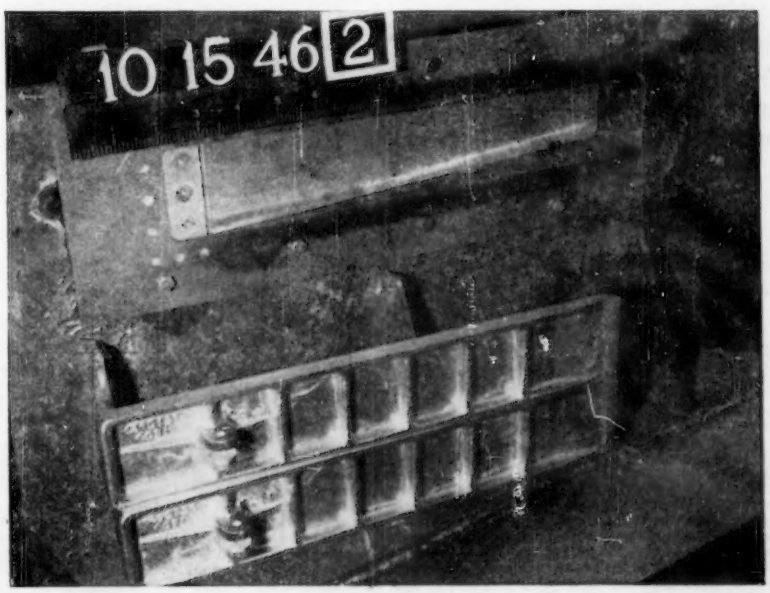


Fig. 6.—Test Housing with Door Open and Extra Frangible Alloy Doors Below for Display.

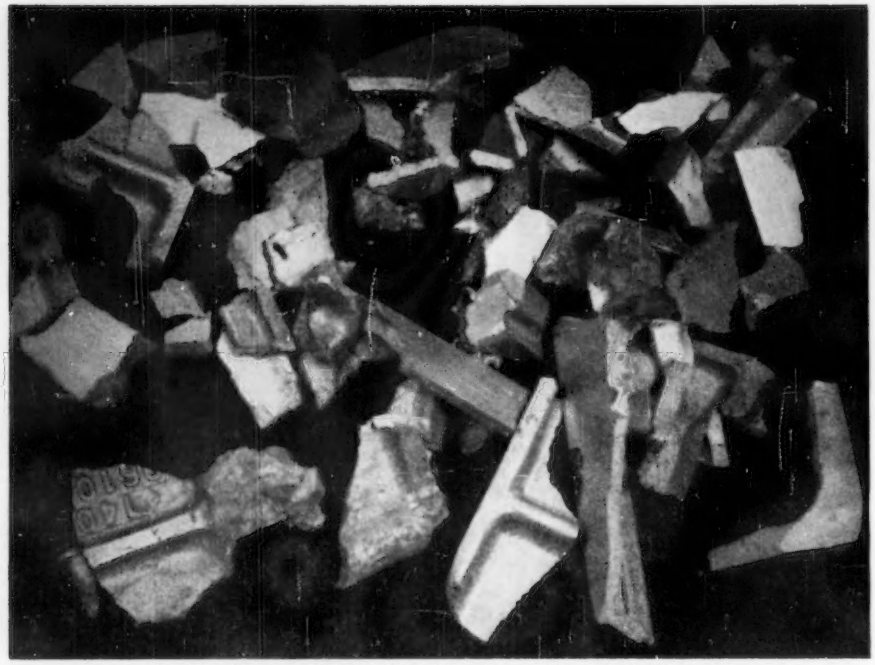


Fig. 7.—Pieces of Frangible Alloy Door After Bullet Impact.

In these tests a corrosion-resistant steel housing similar to the one installed on the airplane was mounted at the muzzle of the 0.50 caliber gun as shown in Fig. 5. An outside view of the housing with the brittle alloy door mounted in its open position is shown in Fig. 6. Two extra cast frangible alloy doors are shown below the mounted specimen. Figure 7 shows some of the pieces of a door that was shot off. All of the rest of the pieces were too small to find at the firing range.

Development of Special Alloy

Description of Frangible Alloy Casting NAA Specification NA2-9006:

This aluminum alloy cast material is brittle and will fracture on impact. It is intended primarily for nonstructural parts such as gun-blast tube doors which upon malfunction will be intentionally destroyed by bullet impact and will shatter into small harmless pieces.

The nominal chemical composition of the alloy tested was: copper, 10 to 13 per cent; magnesium, 1½ to 3 per cent; zinc, 3 per cent maximum; other elements, 1 per cent maximum each and aluminum remainder.[2]

Laboratory Tests of Frangible Alloy Casting Material:

Thirty-six test bars of dimensions specified in Federal Specification QQ-M-151 (Fig. 11B) were cast from two separate melts. The test bars were numbered in the order of pour-off, with numbers 1 to 16 inclusive being cast from melt No. 1 and 17 to 36 inclusive, from melt No. 2. Analyses of the metal are given in Table II.

[2] The alloy was compounded by using Alcoa No. 195 aluminum casting alloy as the base and adding commercial bronze or red brass (that is, an alloy with 80 to 90 per cent copper and balance zinc) and, for magnesium, the Dow H casting alloy.

TABLE II.—CHEMICAL ANALYSIS OF MELTS.

Bar	Melt	Composition, per cent					Remarks
		Copper	Magnesium	Zinc	Silicon	Iron	
No. 1	No. 1	9.57[a]	1.12[a]	0.30	1.07	0.71	First pour-off
No. 16	No. 1	9.90[a]	1.58[a]	0.34	1.18	0.62	Last pour-off
No. 17	No. 2	12.14	2.65	0.58	1.24	0.74	First pour-off
No. 36	No. 2	12.14	2.78	0.60	1.24	0.71	Last pour-off

[a] In processing Melt 1 which was slightly below the required composition, the metal was not held at pouring temperature (1300 F.) long enough to allow all of the copper to go into solution. This was apparent as the heel of the melt contained considerable copper-rich aluminum. The low magnesium content was due to loss by ignition and sublimation during melting.

In processing Melt 2 the procedure was closely supervised. The copper was added after the aluminum became molten and the metal was held at a temperature ranging between 1300 and 1350 F. for a period of 20 min. (A temperature not exceeding 1350 F. is recommended, as above this temperature the metal will become porous due to the absorption of hydrogen.) The magnesium was added immediately before pouring to prevent loss due to sublimation and the melt was stirred thoroughly. The chemical analysis indicates a homogeneous melt with negligible loss of magnesium. (Melt was calculated to lose 0.3 per cent magnesium by sublimation and ignition.) Pouring temperature must not exceed 1300 F. and melt must not be held in a molten condition longer than 1 hr. if sound castings are desired.

Mechanical Properties

Some of the 36 test bars were submitted to various heat treatments as noted in Table III. To determine the effect of machining on the physical properties, the outside skin was machined from bars 34, 35, and 36. After treatment the bars were pulled on a Riehle 20,000-lb. testing machine. It should be noted that since the elongation of this brittle alloy is so low, it is impossible to detect difference between yield strength and ultimate tensile strength, hence values given in the table are considered to be both the yield and tensile values.

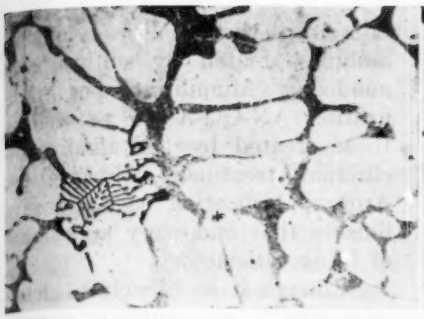
Although an insufficient number of test bars were made to formulate specific strength and heat-treatment requirements for the alloy, reference to the average strengths given in Table III and examination of the photomicrographs in Fig. 8 will lead to the following conclusions:

Precipitation heat treatment (aging) at 340 F. for 4 hr. had relatively little effect on the mechanical properties.

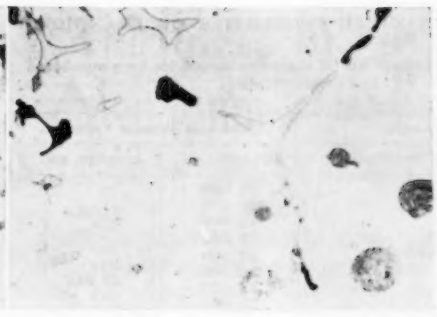
Due to the high copper content of the alloy, solution heat treatment and aging would have relatively little effect as only 2.8 per cent of copper is soluble at a temperature of 840 F. Heat treatment, however, does tend to change the microstructure in that it breaks up the complex eutectic Al-$Cu_2Mg_3Al_5Cu$-Al_2 occurring in the as-cast structure (see Fig. 8) to finely dispersed particles of $Cu_2Mg_2Al_5$ and globules of $CuAl_2$ when solution heat-treated at temperatures in the vicinity of 750 F. (see Figs. 8 (*c*) and (*d*)).

Solution heat treatment in the vicinity of 850 F. tends to break up the complex eutectic to form primary globules of $CuAl_2$ and put the magnesium constituent in solid solution (see Figs. 8 (*e*) and (*f*)). Solution heat-treating temperatures above 900 F. cannot be tolerated as the magnesium constituent tends to burn out (see Fig. 8 (*b*)).

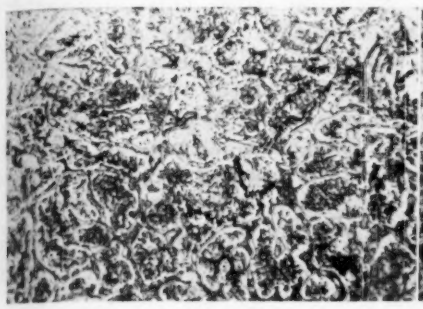
In all instances except those having the magnesium constituent burned out, the bars poured from



(*a*) As-cast structure of bar 18 shows finely dispersed particles of eutectic Al-$Cu_2Mg_2Al_3CuAl_2$ at grain boundaries and "Chinese Script" of dark Alpha AlFeSi. Tensile and yield strengths 28,500 psi. Elongation is less than 0.5 per cent in 2 in.

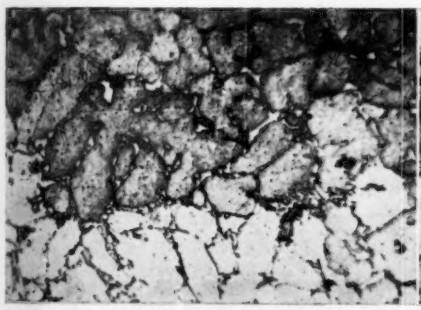


(*b*) Bar 5 "burned" after 15 hr. at 940 F. Large light globules are $CuAl_2$. "Rosettes" are agglomerated spheroid particles of insolubles. Dark areas are voids from which magnesium constituents have burned out. Tensile strength and yield strength, 10,670 psi. Elongation less than 0.5 per cent.

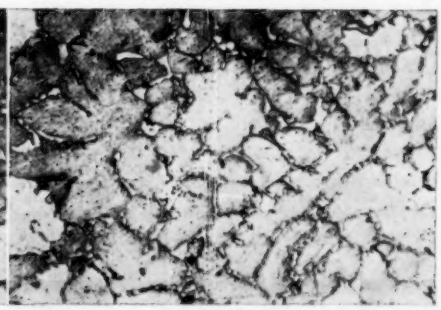


(*c*) Bar 25 after 15 hr. at 720 F. Note intergranular globules of $CuAl_2$ and small particles of eutectic $Cu_2Mg_2Al_3$. Treatment apparently disassociated eutectic Al-$Cu_2Mg_2Al_3CuAl_2$ present in "As-cast" to eutectics $Cu_2Mg_2Al_3$ and $CuAl_2$. Tensile strength and yield strengths 25,625 psi. Elongation less than 0.5 per cent.

(*d*) Bar 27 after 15 hr. at 720 F. and 4 hr. at 340 F. Note similarity in microstructure to that shown in (*c*). Tensile and yield strengths of 26,500 psi. are only slightly better than value of 25,625 psi. for (*c*). Elongation less than 0.5 per cent.



(*e*) Bar 30 after 4 hr. at 860 F. Note globules of $CuAl_2$ at grain boundaries. The eutectic Al-$Cu_2Mg_2Al_3CuAl_2$ in "As cast" condition does not occur since magnesium constituent has gone into solid solution. Tensile and yield strengths 28,100 psi. Elongation was less than 0.5 per cent.



(*f*) Bar 31 after 4 hr. solution heat treatment at 860 F. and 2 hr. of aging at 340 F. Note similarity of the microstructure to that shown in (*e*) showing similar bar without aging. Tensile and yield strengths 29,100 psi. Elongation less than 0.5 per cent.

Fig. 8.—Photomicrographs of Fractured Section of NA2-9006 Frangible Alloy Test Bars (× 100). Keller's Etch.

melt 2 had slightly higher properties than those poured from melt 1. The greatest difference was in the "as-cast" condition.

Comparison of the properties of the machined test bars with those not machined but from the same melt and having the same heat treatment (26,730 *versus* 29,715 psi.) showed that machining the outer skin from the separate cast bars decreased the tensile and yield strengths by approximately 10 per cent.

From the foregoing results the expected range of mechanical properties of the frangible alloy castings is shown in Table IV.

The minimum mechanical properties shown in Table V are considered acceptable for use as gun-blast tube doors.

Gun-Blast Deposit Composition and Properties

A qualitative spectrographic analysis of the gun-blast deposit, which is a hard, black incrustation that is quite difficult to remove, reveals the following approximate composition:[3]

Element	Estimated Percentage
Cu	Major constituent
K	10.0 to 100.0
Pb, and Na, each	1.0 to 10.0
Si, B, Fe, Al, Zn, each	0.1 to 1.0
Mg, Ag, Mn, Ca, each	0.03 to 0.3
Mo	Trace

No sulfates, chlorides, nor nitrates were found to be present. The deposit was found to be highly alkaline (pH = 12 to 13). Spectrographic analysis is unable to reveal the presence of carbon, sulfur, or phosphorus which are also believed to be present.

Gun Blast Deposit Causes Corrosion of Unprotected Frangible Alloy in the Presence of Moisture

This black gun-blast deposit or incrustation when deposited upon frangible alloy castings that had not been given a protective surface treatment was found to be porous and, in the presence of moisture, was found to cause corrosion. A close examination of many samples that had been exposed to the elements for periods of at least a month revealed that a layer of a soft flakey white amorphous substance (believed to be aluminum hydroxide) forms beneath the black deposit. The growth of this product of corrosion causes the black deposit to flake off irregularly and uncover the underlying deposit leaving "white" patches as shown in Fig. 9.

Closer examination of a polished section revealed that the corrosion was due to chemical action between the aluminum alloy crystals and the alkaline gun-blast deposit. The high copper eutectic and constituents at the grain boundaries appeared to be untouched. This is probably due to the fact that both the gun-blast deposit and the ma-

[3] Dr. C. E. Harvey of the Applied Research Laboratories (Glendale, Calif.) devised this method of designating approximate quantitative results on a qualitative spectrographic analysis. The element, which is the most abundant, is listed as the "major constituent," while the remainder of the elements are estimated in tenfold steps.

As an example, a piece of brass alloy with the following *quantitative* analysis:

Copper 60 per cent, zinc 35 per cent, tin 2 per cent, lead 3 per cent

would give the following estimated *qualitative* analysis:

Copper "major constituent," zinc 10–100 per cent, tin 1.0 to 10 per cent, lead 1.0 to 10 per cent

In other words, it is really an expression of the relative intensity of the spectrographic film record and serves only very roughly as an index to *quantity* of each constituent.

TABLE III.—HEAT TREATMENT AND MECHANICAL PROPERTIES OF FRANGIBLE ALLOY TEST BARS.

NOTE 1.—Test specimens in all cases standard cast-to-size 0.505 in. diameter except for bars numbered 34, 35, and 36 which were machined to 0.375, 0.374, and 0.373 in., respectively.
NOTE 2.—Elongation in all cases less than 0.5 per cent.

Bar	Melt	Heat Treatment		Yield and Tensile Values	
		Solution	Precipitation	Strength, psi.	Average, psi.
No. 1	No. 1	None (As cast condition)		24 000	24 560
No. 2				24 125	
No. 3				25 500	
No. 4				24 625	
No. 17	No. 2			30 500	28 860
No. 18				28 500	
No. 19				28 450	
No. 20				28 000	
No. 5	No. 1	940 F. 15 hr.	None	10 675	9 687
No. 6				8 700	
No. 21	No. 2			8 100	7 750
No. 22				7 400	
No. 7	No. 1		340 F. 4 hr.	9 100	9 025
No. 8				8 950	
No. 23	No. 2			7 000	6 925
No. 24				6 850	
No. 9	No. 1	720 F. 15 hr.	None	26 650	26 100
No. 10				25 600	
No. 25	No. 2			25 625	26 485
No. 26				27 350	
No. 11	No. 1		340 F. 4 hr.	25 900	25 750
No. 12				25 600	
No. 27	No. 2			26 500	26 150
No. 28				25 800	
No. 13	No. 1	860 F. 4 hr.	None	27 900	27 550
No. 14				27 200	
No. 29	No. 2			30 625	29 360
No. 30				28 100	
No. 15	No. 1			28 500	28 950
No. 16				29 400	
No. 31	No. 2		340 F. 4 hr.	29 100	29 715
No. 32				29 450	
No. 33				30 600	
No. 34			(Machined)	26 700	26 730
No. 35				26 400	
No. 36				27 100	

trix are high in copper and are therefore cathodic with respect to the aluminum alloy crystals. This is desirable as the corrosion will probably be limited to the first exposed layer of crystals, and will not cause eventual disintegration of the casting as might easily occur if the material at the grain boundaries were attacked.

TABLE IV.—MECHANICAL PROPERTIES OF FRANGIBLE ALLOY CASTINGS.

Condition	Tensile and Yield (Range), psi.	Elongation in 2 in., per cent
As cast	24 000 to 28 000	Less than 0.5
Solution heat-treated 860 F., 4 hr.	27 000 to 30 000	Less than 0.5

PROTECTIVE TREATMENTS FOR FRANGIBLE ALUMINUM CAST ALLOY

Although under normal operating conditions almost any of the normal protective coatings such as anodizing, primer, and lacquer would be satisfactory, in this application the high temperatures as well as the abrasive effect of the gun blast make adequate surface protection quite a problem.

As the frangible alloy has from 10 to 13 per cent copper, chromic acid anodizing is unsatisfactory because of the selective etching of the alloy. Two other chemical surface treatments that would meet Army and Navy requirements could be applied with facilities available. Samples treated by sulfuric acid anodizing (Alumiliting) per Specification AN-QQ-A-696 as well as those treated by the alkaline dichromate treatment (Alroking) per Army Specification 98-20007 gave finishes that had every appearance of being satisfactory.

Although it is difficult to determine exactly what surface temperatures are reached when in the vicinity of the gun blast, it is not believed that they exceed 700 F. for more than a few seconds at a time and then only immediately adjacent to the gun muzzle. Fortunately, in those areas in which high temperatures exist the erosive effect of the blast also keeps the surface clean so that no corrosive effect is noticeable. In the other areas, less violently affected, the build-up of blast-gas deposit causes corrosion, but these areas, since their temperatures probably never exceed 400 F., can be more readily protected by heat-resisting organic or inorganic finishes such as perhaps a silicone baking enamel. Corrosion tests on treated specimens have not been completed.

TABLE V.—MINIMUM MECHANICAL PROPERTIES FOR GUN-BLAST TUBE DOORS.

Condition	Strength	Separately Cast Test Bars	Test Bars Machined from Castings
As cast	Tensile strength	24 000 psi., min.	21 500 psi., min.
	Elongation	0.5 per cent, max.	0.5 per cent, max.
Solution heat-treated condition (840 F., 4 hr.)	Tensile strength	27 000 psi., min.	24 000 psi., min.
	Elongation	0.5 per cent, max.	0.5 per cent, max.

Fig. 9.—Scraping Off Black Blast Deposit and White Corrosion Product from Weathered Sample (X 6).

Measurement of Thickness of Oxide Coatings on Aluminum Alloys

By Ralph B. Mason[1] and William C. Cochran[1]

MEASUREMENTS of the thickness of the oxide coatings formed on aluminum alloys by various electrochemical and chemical treatments are of special value in the control of the several coating processes now being widely used and in the development and evaluation of new coating processes. Characteristics of oxide-coated aluminum such as resistance to corrosion and to abrasion and the ability to sorb dyes or pigments are influenced largely by the thickness of the oxide coating. In the anodic treatment of aluminum, the thickness of the oxide coating formed is dependent to an important degree on the concentration and temperature of the electrolyte, the time of treatment, and the current density employed. Of the various physical measurements made on oxide-coated aluminum, those dealing with the thickness of the oxide coating are the most useful and practical.

A number of different methods are in use at present for determining the thickness of oxide coatings on aluminum alloys. These include the micrometric, the voltage breakdown (3),[2] the microscopic (4, 5), and the stripping methods (4, 5). Of these, the microscopic and stripping methods are the ones most generally used since they give the most accurate and consistent results. These methods, however, have the disadvantage that they are slow and mutilate the specimen. Recently a new electrical method has been developed for measuring the thickness of oxide coatings. This method employs an instrument designated as a Filmeter and is both rapid and nondestructive. Since there is a real need for a test of this character, an investigation was made to determine the practicability of using the Filmeter for measuring oxide coatings on aluminum alloys. The results of this investigation are given in this paper together with a comparison with the results obtainable by the microscopic and the stripping methods.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Assistant Chief, Metallography Division, and Research Engineer, respectively, Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

The Filmeter and Its Operation

The Filmeter or electrical gage (1, 2) is a portable, battery-operated electronic beat-frequency oscillator contained in a 7 by 7 by 7-in. steel case weighing about 11 lb. complete, manufactured by the American Instrument Co. of Silver Springs, Md. This instrument has two oscillator circuits, one of which is fixed as a reference standard; the other is variable. The inductance coil of the variable oscillator circuit is mounted on the end of an insulated piston which can move against the pressure of a spring in an aluminum cylinder and is connected to the instrument by a shielded cable. This pick-up coil is placed on the coating to be measured; constant and uniform pressure is maintained by a spring in the shielded aluminum cylinder. The current flowing in the coil induces eddy currents in the base metal under the oxide coating. The intensity of the eddy currents varies with the distance between the coil and the base metal and the inductance of the test coil changes proportionally to the intensity of the eddy currents and in turn controls the frequency of the oscillator current. Change in frequency is measured by rotating a 4-in. dial of a variable air condenser until the frequency returns to its original value. By means of earphones the operator can determine when the two oscillator circuits are tuned to the same frequency.

In operation, the calibrated dial of the air condenser used for measuring the thickness is set at zero and the pickup is placed on bare metal which must be of the same alloy, temper, and smoothness as the base metal under the coating being measured. The small dial of the adjusting air condenser is then turned to the point where the tone just ceases to be audible in the phones. At this point the oscillator circuits have the same frequency. The pickup coil is then placed on the coating to be measured and a tone is heard again. The calibrated dial for measuring thickness is rotated until this tone just stops. At this point the reading of the dial is taken and by applying a calibration factor the thickness of the oxide coating is found.

While it is possible to calibrate the condenser dial directly in millimeters or inches, it is usually more practical to establish a calibration curve for the dial readings. The instrument has been so designed that the distances of the pickup coil from the metal surface are directly proportional to the dial readings, thus making the calibration curve a straight line passing through the origin. It is possible, therefore, to calibrate the instrument by determining the dial reading for a film of known thickness and thus establish one point on a calibration curve. A sample of mica or lacquer film of known thickness is furnished with the instrument for the purpose of calibration.

If a piece of bare metal of the same smoothness and alloy as the piece of metal under the coating being measured is not available and it is not objectionable to have a small area of the oxide coating removed from the specimen, there is an alternate method for setting the zero point. A drop of 10 per cent aqueous caustic soda solution placed on the oxide coating will remove enough oxide to enable the operator to place the spacer pin (diameter about) of $\frac{1}{16}$ the pickup coil against the bare metal and obtain a zero setting. It is necessary only that this pin, whose pur-

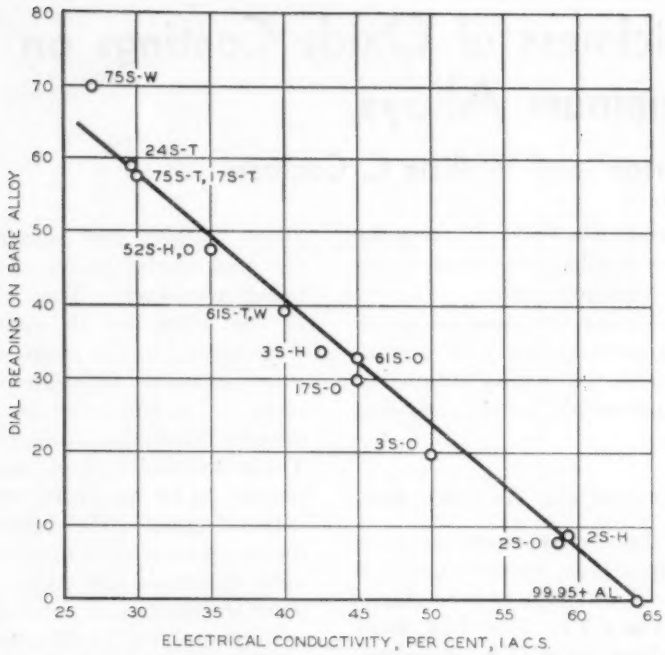


Fig. 1.—Dial Readings of the Variable Air Condenser as a Function of the Electrical Conductivity of the Metal.

pose is to provide a constant distance between the surface and the pickup coil, touch the bare metal. The caustic solution should be washed off as soon as gassing indicates that the bare metal has been reached. It may be necessary to apply fresh caustic solution before the coating is completely dissolved away, but the total time required should not be more than 2 or 3 min.

The principal limitation of the Filmeter is that curved or rough surfaces cannot be measured accurately. The manufacturer has recommended that if the measurements are to be made on concave or convex surfaces, the radius of curvature of the specimen must be 6 in. or greater. The aluminum-base metal should be at least 0.011 in. thick and the surface roughness should be less than 2 per cent of the coating thickness. There is no limitation to the maximum thickness of the base metal. In the original article on the electrical gage (2) it is stated that the edge of the pickup coil should not be placed nearer than ½ in. to the edge of the specimen, otherwise the inductance of the oscillator coil will be affected.

Testing and Calibration of the Filmeter

The following experiments were carried out to test the Filmeter for the measurement of the thickness of anodic oxide coatings on aluminum and its alloys and at the same time to find out whether different calibration factors are necessary for oxide coatings formed on the various aluminum alloys.

It was decided to calibrate the condenser dial readings of the instrument against the thickness measurements obtained by the microscopic method. Assuming a plane, smooth surface, the electrical gage readings that one gets on an oxide-coated specimen depend on two factors: (1) the distance between the pickup coil and the base metal, and (2) the conductivity of the base metal. It is known that the eddy currents which change the inductance of the pickup coil vary in intensity with the conductivity of the base metal. Therefore, to start with, it was deemed necessary to establish a relationship between the conductivity of the base metal and the Filmeter readings made on it. To accomplish this, a piece of high-purity aluminum sheet (99.95 + per cent purity) was used for setting the zero point. The pickup coil was then placed on different bare aluminum alloys and the calibrated condenser dial rotated until the tone just stopped in the phones. These readings were a measure of the difference in conductivity of the pure aluminum specimen and the alloy. The higher the condenser dial reading of the Filmeter, the lower the conductivity of the alloy. The electrical conductivity of high-purity aluminum is 64 per cent of the International Annealed Copper Standard. Since this value is higher than that for any aluminum alloy, it is possible to use high-purity metal as a reference standard for measuring the electrical conductivity of aluminum alloys with the Filmeter.

To establish the graph giving the relationship between the electrical conductivity and the condenser dial reading of the Filmeter on the bare alloy, several alloys whose conductivities were known were carefully buffed to present a smooth surface. The specimens were 2 by 6 by 0.064 in. At least three readings were made on each bare alloy with the electrical gage. The average of these values for each alloy was then plotted against conductivity as shown in Fig. 1. The graph is practically a straight line. Having established this relationship the next step was to see whether there was any relationship between the electrical conductivity of the alloy and the calibration factor or to prove that the calibration factor was not appreciably affected by the electrical conductivity of the metal.

About two dozen alloy specimens were anodically coated and their coating thickness measured by the electrical gage and by the microscope. The procedure was as follows:

Panels of each different alloy, 2 by 6 by 0.064 in., were buffed on one side. They were then anodically coated for approximately 1 hr. in a 15 per cent by weight sulfuric acid electrolyte at 70 F., with a direct current density of about 12 amp. per sq. ft. When the coating was completed, a 1-in. strip was cut off one end of each panel and used to measure the coating thickness by the microscopic method. Next, one half of the remaining panel was stripped of its oxide coating by means of the standard phosphoric-chromic acid stripping solution (4). Finally, the coating thickness of each panel was measured with the Filmeter, using the stripped portion of each specimen to adjust the instrument to the zero point. Thus the bare metal

used for setting the zero point was exactly the same as the base metal under the oxide coating, since the stripping solution used does not attack aluminum. At least three readings were made with the Filmeter at different points on the oxide coating. The thickness of oxide coating in mils obtained by the microscopic method was then divided by the average of these readings to get the proper calibration factor for each different alloy.

TABLE I.—THICKNESS MEASUREMENT OF ANODIC COATINGS ON DIFFERENT ALUMINUM ALLOYS WITH THE MICROSCOPE AND FILMETER.

	Thickness by Microscope, mils	Thickness by Filmeter,[a] mils
No. 1 Reflector	0.95	0.98
No. 2 Reflector	1.05	1.05
2S-O	1.09	1.09
2S-H	0.94	0.94
3S-O	0.92	0.90
3S-H	0.70	0.72
4S-O	0.73	0.73
4S-H	0.73	0.74
17S-O	0.61	0.62
17S-T	0.71	0.72
24S-T	0.84	0.85
52S-H	0.59	0.59
52S-O	0.86	0.85
53S—as extruded	0.88	0.87
61S-O	0.84	0.84
61S-W	0.95	0.94
61S-T	0.97	0.97
63S—as extruded	1.06	1.05
63S-O	0.90	0.91
63S-T	1.22	1.25
75S-O	0.60	0.61
75S-W	0.67	0.67
75S-T	0.66	0.64
Alclad 24S-T	1.11	1.12

[a] Calibration factor of 0.014.

NOTE.—The thickness by microscope is an average of ten readings. The thickness by Filmeter is an average of at least three readings.

Figure 2 shows the results of plotting electrical conductivity and the calibration factor for each alloy measured. It appears that the calibration factor is, for all practical purposes, independent of the electrical conductivity of the base metal. For the particular Filmeter used in these tests, a calibration factor of 0.014, which is a fair average, can be used without introducing an important effect in the thickness measurements. It is to be expected that other instruments may have a different calibration factor. The calibration factor should be checked occasionally on a panel having a heavy oxide coating of known thickness and area, for making the zero setting, from which the coating has been removed with phosphoric and chromic acids.

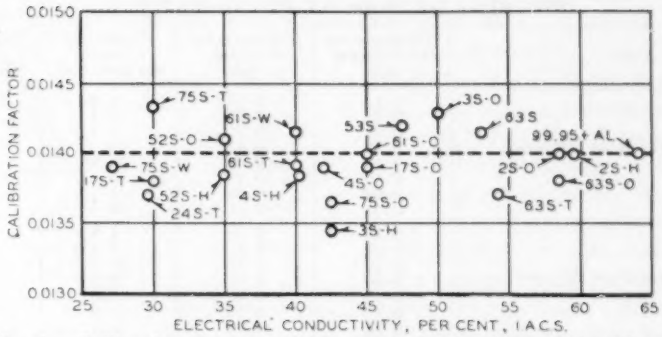


Fig. 2.—Calibration Factor and Electrical Conductivity of the Metal.

Table I shows the thickness of oxide coatings as measured by the microscope and by the Filmeter. The factor of 0.014 was used for converting all the dial readings to thickness in mils. For the majority of the alloys the coating thicknesses obtained by the two methods do not differ by more than a few per cent. The nominal chemical composition of the aluminum alloys on which the thickness of oxide coatings has been measured is shown in Table II.

Thinking that perhaps the presence of paramagnetic material in an oxide coating would increase the apparent thickness measurement obtained with the Filmeter, porous oxide coatings were impregnated with iron oxide and nickel oxide and measurements were made before and after impregnation. At the most, an increase in apparent thickness of about 0.01 to 0.02 mil was noted.

TABLE III.—RESULTS OF MEASUREMENT OF OXIDE COATINGS OF VARIOUS THICKNESSES.

Alloy	Approximate Time of Anodic Coating, min.	Thickness by Microscope, mils	Thickness by Filmeter,[a] mils
99.95+ per cent Al	15	0.29	0.29
99.95+ per cent Al	30	0.52	0.45
99.95+ per cent Al	45	0.71	0.71
99.95+ per cent Al	60	0.98	0.98
2S-H	15	0.29	0.26
2S-H	30	0.42	0.43
2S-H	45	0.75	0.74
2S-H	60	0.96	0.90
24S-T	15	0.20	0.20
24S-T	30	0.34	0.34
24S-T	45	0.63	0.63
24S-T	60	0.84	0.84

[a] Calibration factor of 0.014.

NOTE.—The thickness by microscope is an average of ten readings. The thickness by Filmeter is an average of at least three readings.

In order to determine whether the calibration factor of 0.014 would hold for different thicknesses of oxide coating on any one alloy, a series of panels of high-purity aluminum sheet, 2S-H and 24S-T alloys, was anodically coated for 15, 30, 45, and 60 min. in sulfuric acid under standard conditions. These panels were treated in the same manner as those in Table I. Table III gives a comparison of the thickness data obtained with the microscope and the Filmeter. In most cases, the agreement between the two methods is very good and it is safe to conclude that the calibration factor for the Filmeter is the same over the entire range, and that it does not

TABLE II.—NOMINAL COMPOSITION OF WROUGHT ALUMINUM ALLOYS.[a]

Alloy	Per Cent of Alloying Elements—Aluminum and Normal Impurities Constitute Remainder					
	Copper	Silicon	Manganese	Magnesium	Zinc	Chromium
2S	..	...	...	...	...	..
3S	..	...	1.2	...	...	..
4S	..	...	1.2	1.0	...	..
17S	4.0	...	0.5	0.5	...	..
24S	4.5	...	0.6	1.5	...	..
52S	..	...	...	2.5	...	0.25
53S	..	0.7	...	1.3	...	0.25
61S	0.25	0.6	...	1.0	...	0.25
63S	..	0.4	...	0.7	...	..
75S	1.6	...	0.2	2.5	5.6	0.3

[a] Heat-treatment symbols have been omitted since composition does not vary for different heat-treatment practices.

TABLE IV.—COMPARISON OF THICKNESS MEASUREMENTS MADE BY THREE DIFFERENT METHODS ON ALCLAD MATERIAL.

Alloy	Thickness by Microscope, mils	Thickness by Filmeter, mils	Weight of Coating, mg. per sq. in.	Thickness by Stripping Method, mils
No. 2 Reflector Sheet (3S core)	0.14	0.14	4.9	0.11
	0.22	0.25	10.4	0.24
	0.24	0.21	9.8	0.22
	0.33	0.33	14.2	0.33
	0.43	0.44	18.9	0.43
	0.45	0.48	20.9	0.48
	0.69	0.69	31.2	0.72
	0.91	0.91	40.8	0.94
No. 2 Reflector Sheet (2S core)	0.15	0.10	4.8	0.11
	0.22	0.24	9.4	0.21
	0.23	0.27	10.3	0.23
	0.30	0.33	13.8	0.32
	0.47	0.50	19.8	0.46
	0.70	0.77	29.9	0.69
	0.94	0.96	39.4	0.91
Alclad 75S (75S alloy core, 72S alloy coating)	0.23	0.24	10.0	0.23
	0.43	0.51	20.4	0.47
	0.67	0.72	30.2	0.70
	0.88	0.95	40.2	0.93

NOTE.—The thickness by microscope is an average of ten readings. The thickness by Filmeter is an average of at least three readings.

vary significantly with thickness of the oxide coating.

Thus far the thickness values obtained with the Filmeter have been compared with those obtained with the microscope. At this point it is desirable to give some thickness data obtained by stripping and weighing and to compare the three methods. The stripping method, employing the analytical balance for determining weight of coating, was developed for laboratories not equipped for metallographic examination. For many purposes the weight of oxide coating per unit area is just as useful as the measurements of thickness and besides can be determined very accurately.

In the stripping method a sample of oxide-coated aluminum of known area is carefully weighed on an analytical balance and then immersed in a 5 per cent solution of phosphoric acid containing about 2 per cent chromic acid anhydride at 180 F. for 5 min. or until all the oxide coating is removed. After washing, the specimen is dried and weighed again. The weight of oxide coating is obtained by difference and the thickness found by dividing the weight by the density. When the density of the oxide is known accurately, this method gives consistent and reliable results. The method was originally developed for coatings on high-purity aluminum but has been extended to cover most of the wrought aluminum alloys. It is not suitable for use on some castings.

Alclad products are anodically coated in many cases, and it was deemed desirable to compare the three methods of measuring oxide coatings on this type of material. Specimens of No. 2 Reflector sheet[3] with 2S and 3S cores and of Alclad 75S sheet were anodically coated for 15, 30, 45, and 60 min. and handled in the same way as those in Table I except that the panels were carefully weighed before and after stripping one half the surface area in the hot mixture of phosphoric and chromic acids. The area of the stripped surface including the edges was carefully measured to find the weight of coating per square inch. Dividing by the density of the oxide coating (in this case 43 g. per cu. in.), the thickness of the coating was obtained. The thickness data obtained by the three methods are recorded in Table IV. It is apparent that some of the Filmeter values are somewhat high on the Alclad 2S and 75S.

The thicknesses of oxide coatings on the panels of No. 2 Reflector sheet with the 3S core (Table IV) were measured, using untreated material for the zero setting. The error in coating thickness introduced by taking the zero setting on the untreated panel has been plotted against the decrease in thickness of alclad layer in Fig. 3. When the zero setting is made on an untreated specimen of No. 2 Reflector sheet with a core of 3S metal, the error in thickness measurements of oxide coatings progressively increases as the time of anodic treatment increases. In the Alumilite process a certain amount of the alclad surface is used up as the oxide coating is formed and as the oxide coating increases in thickness the thickness of the alclad surface layer decreases. Consequently, the pickup coil of the Filmeter is separated from the poorly conducting 3S core material by less and less of the highly conducting alclad layer as the time of anodic treatment increases. When the alclad coating has about the same electrical conductivity as the core material, for example No. 2 Reflector sheet with a 2S core, it makes little difference in

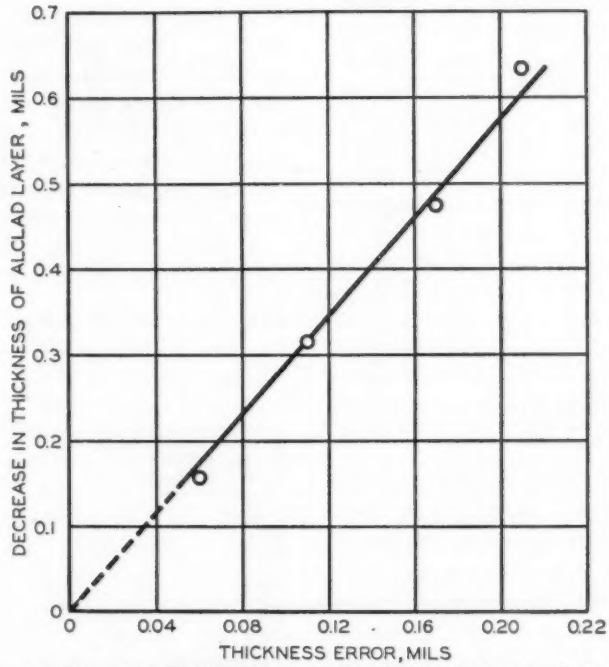


Fig. 3.—Apparent Errors in Thickness of Oxide Coating Introduced by Variations in Thickness of Alclad Layer.

[3] No. 2 reflector sheet is a composite product having a coating or coatings of high-purity aluminum and a core of either 2S or 3S alloy.

TABLE V.—THICKNESS MEASUREMENTS ON VARIOUS ALUMINUM ALLOYS.

Density values for sealed oxide coatings from unpublished data.

Density on 24S-T = 33 g. per cu. in.
Density on 75S-T = 38 g. per cu. in.
Density on Others = 43 g. per cu. in.

Alloy	Thickness by Microscope, mils	Thickness by Filmeter, mils	Weight of Coating, mg. per sq. in.	Thickness by Stripping Method, mils
75S-T	0.22	0.27	8.73	0.23
61S-T	0.24	0.24	10.2	0.24
24S-T	0.20	0.21	6.65	0.20
52S-H	0.24	0.24	10.3	0.24
3S-½H	0.25	0.21	10.1	0.23
2S½H	0.24	0.23	10.3	0.24

NOTE.—The thickness by microscope is an average of ten readings. The thickness by Filmeter is an average of at least three readings.

the measurement of the oxide coating thickness whether the zero setting is made on the untreated material or on the stripped area. However, for making accurate measurements with the Filmeter it is good practice to make the zero setting on a stripped area, especially when the alloy is not known or the material is of the alclad type.

In order to compare the three methods of measuring oxide coating thickness further, another series of aluminum alloy panels was prepared with approximately 20-min. coatings, water-sealed. After removing strips for measurement with the microscope, the thickness of oxide coating was measured with the Filmeter. The same specimens were weighed, stripped, and weighed again to determine the weight of oxide coating. The area was accurately measured and the weight in grams per square inch divided by the density to give the thickness in inches. The results of this series of measurements are shown in Table V.

The measurements so far reported for the Filmeter have been carried out under good laboratory conditions. To obtain accurate measurements the surface roughness should not exceed 2 per cent of the thickness of the coating being measured. To illustrate the effect of roughness of surface on the Filmeter measurements, two simple experiments will be described. In the first experiment, the surface of a 24S-T specimen with an oxide coating 0.37 mil in thickness was slightly indented. When the pin of the oscillator coil was placed in this indentation there was no tone in the circuit, indicating that the coil was as close to the aluminum surface as when placed on bare metal. In this case, the depth of the indentation was as great as the thickness of the oxide coating. Making a measurement with the pin of the oscillator coil in the indentation, the instrument would record a coating thickness of zero. Turning the specimen over and centering the pin of the oscillator coil on the slightly elevated area opposite the indentation, the Filmeter gave a thickness reading of about 0.69 mil, an error of nearly 90 per cent.

In the second experiment on roughness of surface, two specimens of 2S sheet were uniformly roughened by etching. One of the specimens was anodically coated for about 1 hr. to give a thick oxide coating and one half the coating was stripped in phosphoric-chromic acid. The Filmeter values for coating thickness were 1.11, 0.87, or 0.75 mils depending on whether the zero setting was made on smooth metal, the stripped surface, or the originally etched surface. The second value where the zero setting was made on the stripped area is very nearly correct. Considering the three values, the anodic treatment apparently has some smoothing action on the original rough surface. As an additional check the Filmeter was set to zero on a smooth bare piece of 99.95+ per cent aluminum and the following dial readings obtained, namely, 9.7, 27.9, and 37 depending on whether the oscillator coil was placed on smooth 2S, the stripped area, or the original etched surface. The Filmeter might possibly be used to obtain a quantitative figure for the roughness of a surface.

CONCLUSIONS

From this investigation of the use of the Filmeter for measuring the thickness of oxide coatings on aluminum alloys, it is concluded that this instrument provides a new and useful means for checking thickness and uniformity of oxide coatings. The measurements can be made rapidly without destruction of the part and with an accuracy of the same degree as that obtained by the more time-consuming microscopic and stripping methods. Accuracy of the measurements, however, depends largely on obtaining a satisfactory zero setting for the different aluminum alloys and tempers that may be involved and on having surfaces of suitable flatness and smoothness. The zero setting varies as the conductivity of the alloy being measured. It is necessary, therefore, to obtain a zero setting on a sample of the same composition or temper before making a measurement or to strip a small area of the coating by chemical means and make the zero setting on an uncoated portion of the sample being measured. In addition to measuring the thickness of the oxide coating on aluminum alloys, the Filmeter can be used to give a rough measure of the conductivity of these alloys and in some cases provide an approximate means of alloy identification. With the proper technique, it is also possible to detect differences in the thickness of alclad coating layers on core materials which are of lower conductivity than the coating. Finally the Filmeter should prove to be a very useful tool for the routine checking of oxide coatings on wrought aluminum alloys.

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Sensitometry of Radiographic Films Exposed to Two-Million-Volt X-Rays*

By E. A. Burrill[1] and W. W. Buechner[2]

THE wartime development of precision 2-million-volt electrostatic X-ray generators and associated radiographic techniques by the High Voltage Laboratory of Massachusetts Institute of Technology[3] has led to a greater use of 2-million-volt X-rays for nondestructive testing by the U. S. Navy and other organizations. Consequently, it seems desirable to make available some of the results of this research and development program to those interested in radiography with high-voltage radiations. The work at this laboratory included a study into the properties of radiographic films exposed to this high-voltage radiation. It was the purpose of the investigation described below to develop X-ray film techniques which would utilize to best advantage the high definition, good sensitivity, and broad range of latitude obtainable with 2-million-volt d-c. radiation.

Eight commercially available radiographic films were investigated as to their response both to the radiation and to various processing techniques. From this sensitometric information, films were chosen which are particularly useful with 2- million-volt X-rays. Processing methods were developed which were found to yield improved results on these X-ray films. The film characteristic curves obtained and the exposure-thickness technique charts for this high-voltage radiation can be effectively used together in predicting radiographic exposures for any film density and speed and for any object thickness. These graphs shorten considerably the time normally spent on trial exposures and permit radiography of very heavy metal sections with confidence.

Experimental Method

The radiographic films examined were exposed beneath flat steel plates ranging in thickness from 2 to 8 in. at a constant target-to-film distance of 24 in. at 1 and 2 million volts. Because the characteristics of the various films appeared to be independent of thickness and voltage in this range, the data obtained through 2 in. of steel at 2 million volts are considered typical and are used as the basis of the curves included in this paper.[4]

The X-ray target had an inherent filtration equivalent to 0.7 in. of steel. To reduce room scattering, the X-ray beam was defined by a thick lead shield which reduced the intensity of all but a 20-deg. cone of radiation by a factor of approximately 1000. The films were sandwiched between lead-antimony foils 0.005 in. thick in cardboard cassettes. The foils had an intensification factor ranging from 2 to 3 depending on the film type used. A sheet of lead $\frac{1}{4}$ in. thick was placed directly over the cassettes to screen out very soft radiation from the steel and from the surrounding walls. To reduce back scattering, the cassettes were protected by a barrier of lead blocks 3 in. thick. Each point on the resulting characteristic curves represents an individual exposure. It is felt that this method yields a close approximation of actual radiographic conditions and eliminates some of the obscurities of step-wedge methods and of simultaneous exposures at varying distances from the X-ray source.

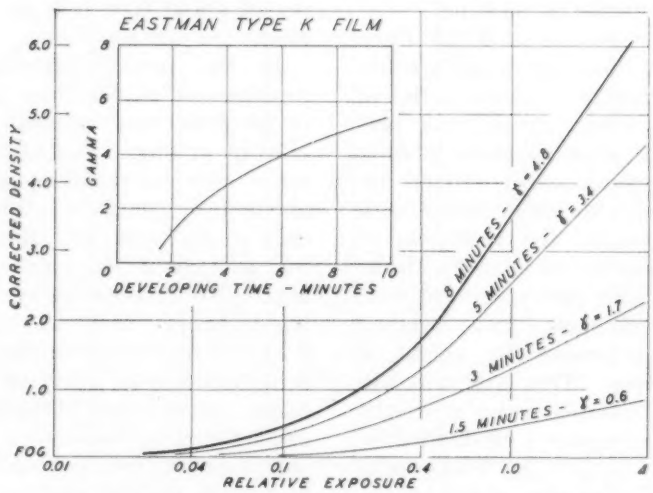

Fig. 1.—H & D Characteristics of Eastman Type K Film.

The exposed films were cut into several strips and developed in Eastman Kodalk X-ray developer for various times. (The basis for the choice of this developer is discussed below.) The wash water and fixing solutions were kept within 2 or 3 F. of the developer temperature by constant circulation of the water in a three-partition X-ray film-processing tank. The film strips representing a complete characteristic curve were clipped to a multiple

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* Presented at a technical papers meeting of Committee E-7 on Radiography held at the Fiftieth Annual Meeting, Am. Soc. Testing Mats., Atlantic City, N. J., June 16, 1947.

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[3] This research was done under National Defense Research Committee Contract No. OEMsr-294 at M.I.T. and is reported in Office of Scientific Research and Development Report No. 4488 (7 volumes). The sensitometric information discussed here is included in Vol. 6 of the OSRD report.

[4] The characteristics of Eastman Type A film exposed to radium gamma radiation were found to be substantially the same as those at 2 million volts. This similarity enabled short sensitometric tests to be made with radium when the 2-million-volt generators were in use.

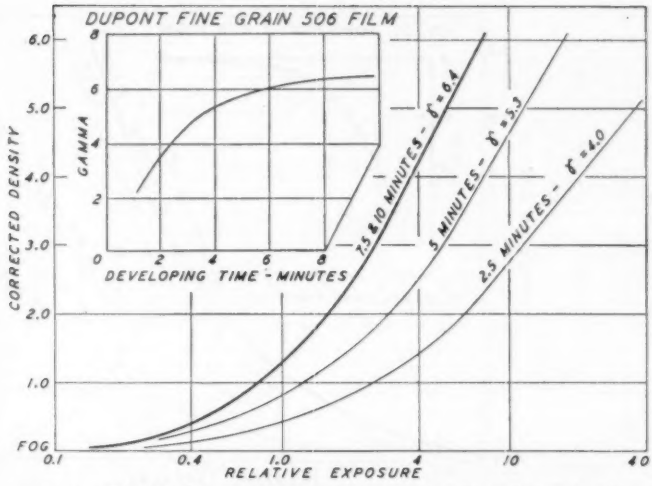


Fig. 2.—H & D Characteristics of du Pont Fine Grain 506 Film.

dental film hanger and developed simultaneously. Every 2 min. the strips were agitated in the solution for approximately 5 sec.

A Capstaff-Purdy transmission densitometer was used for all density readings. Reproduction to within 0.02 unit density was obtained in the majority of the readings. In the examination of the coarser grained emulsions, it was necessary to oscillate the film rapidly in order to obtain a uniform-appearing central field in the densitometer eyepiece. Although this density comparator was capable of measuring densities up to 3.0, it was found that higher values were needed to obtain an informative film characteristic curve. Because high-intensity-viewing techniques were often employed at the High Voltage Laboratory to increase the effective latitude of the film and to obtain better sensitivities by exposure to higher gammas, it was necessary to include the density range from 3.0 to 6.0 in the sensitometric curves. From theoretical predictions and experimental verification, it was found that the sensitivity (the ability to record small thickness differences) of the radiation is directly dependent on film contrast or gamma. Because the majority of the films examined do not attain their maximum value of gamma before a density of about 2 is reached, exposures to densities beyond this range are necessary to yield radiographs of best sensitivity. The manner in which the higher values of density were measured is as follows:

The emulsion on one side of the doubly coated film was scraped off with a razor blade after the gelatin layer had been softened somewhat with water. The density reading obtained after this procedure was equal to one-half the total density plus the film-base density. By doubling the readings and subtracting the base density, a value for the total density to within approximately 0.04 unit was obtained.

Because of the variation in inherent fog density between different types of films, developing conditions, and ages of the same type of film, all density readings were corrected to eliminate the fog, thus comparing all films on a more equal basis. Instead of subtracting the density of an unexposed (but developed) film from all values of density, the fog correction formula of Meidinger[5] was used. This relationship is an approximation but is adequate for this work in view of the processing and emulsion variations. The Meidinger formula follows:

$$D_f = \{(D_m - D)/(D_m - F)\}F$$

where

D_f = fog density correction (density to be subtracted from D, the density under consideration),
D_m = maximum density obtainable with infinite exposure and development, and
F = fog density of unexposed film.

D_m was estimated by extrapolating trends observed in the sensitometric measurements of various films. Although the values of D_m used in these corrections are very approximate, it was found that the Meidinger relationship is very insensitive to D_m. F was obtained for each film and for each development time by including an unexposed film with those processed for a particular characteristic curve. The superposition of corrected curves of three emulsion batches of the same type of film having different fog densities (varying from 0.3 to 0.9 for 8-min. development at 68 F. in Kodalk X-ray developer) indicates the validity of this correction method.

Results

The eight radiographic films examined are as follows:

Eastman Kodak Industrial X-Ray Film, Types, A, F, K, and M
Ansco Film, Types Superay A No. 674, Superay B No. 874, and Industrial No. 870
duPont Film, Fine-Grain Type No. 506

[5] C. E. K. Mees, "Theory of the Photographic Process," Macmillan & Co., New York, N. Y. (1942), p. 649.

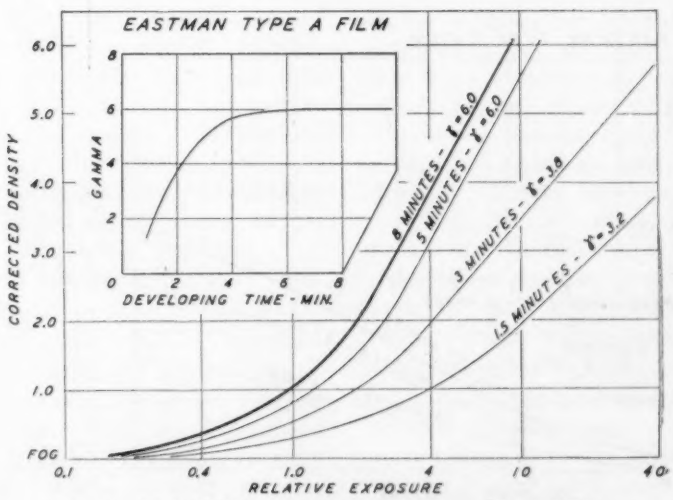


Fig. 3.—H & D Characteristics of Eastman Type A Film.

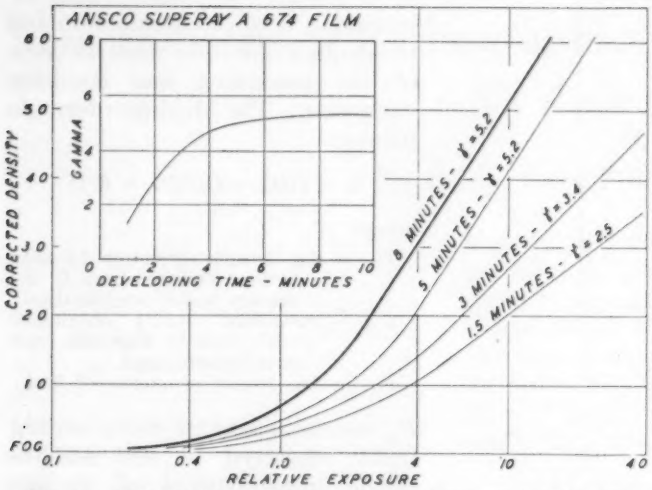


Fig. 4.—H & D Characteristics of Ansco Superay A 674 Film.

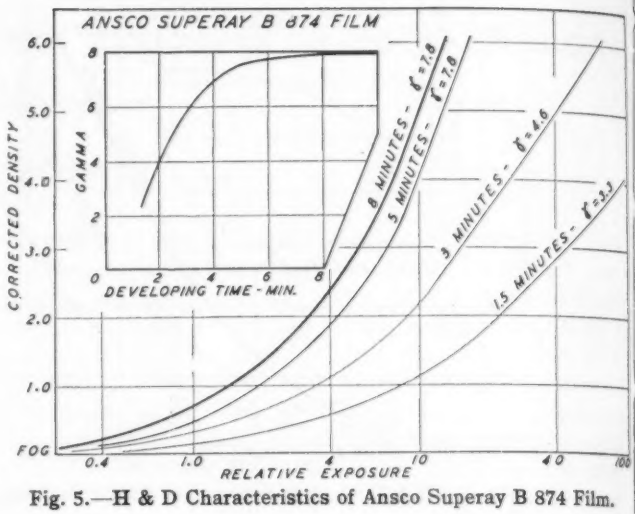


Fig. 5.—H & D Characteristics of Ansco Superay B 874 Film.

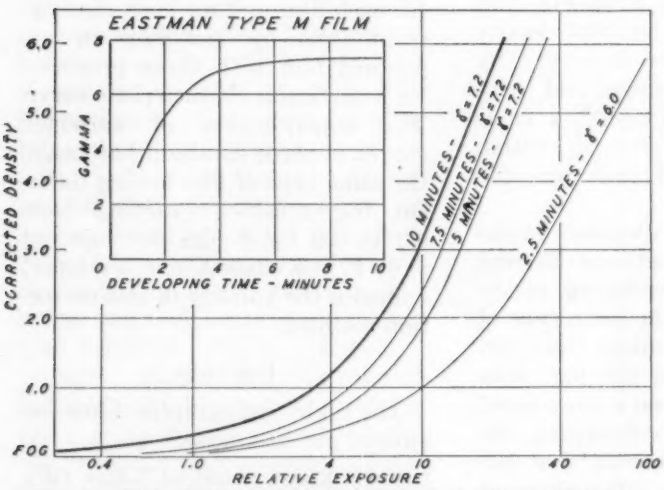


Fig. 6.—H & D Characteristics of Eastman Type M Film.

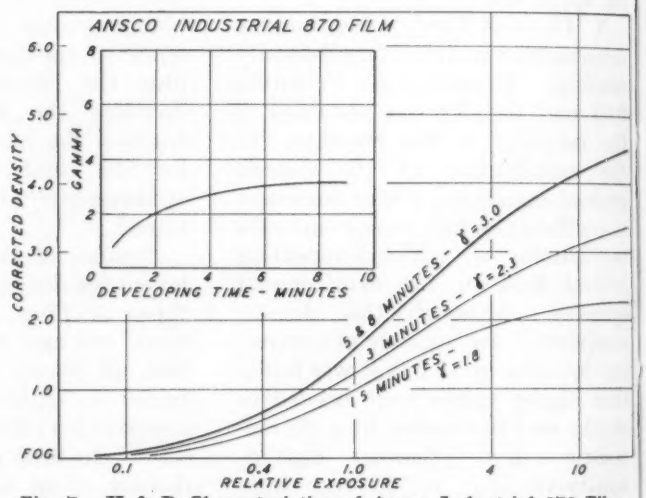


Fig. 7.—H & D Characteristics of Ansco Industrial 870 Film.

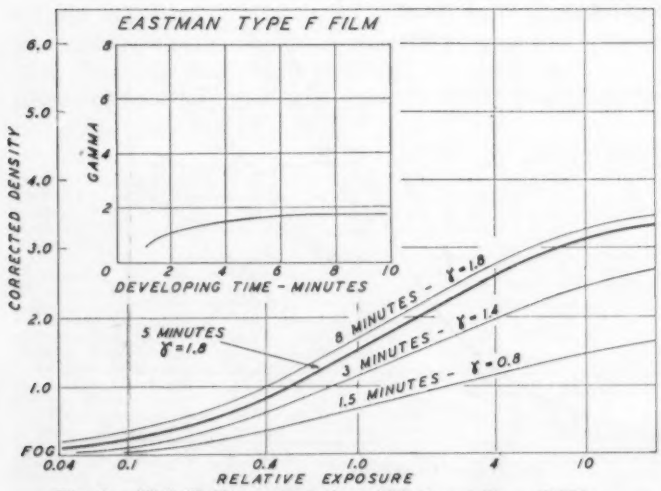


Fig. 8.—H & D Characteristics of Eastman Type F Film.

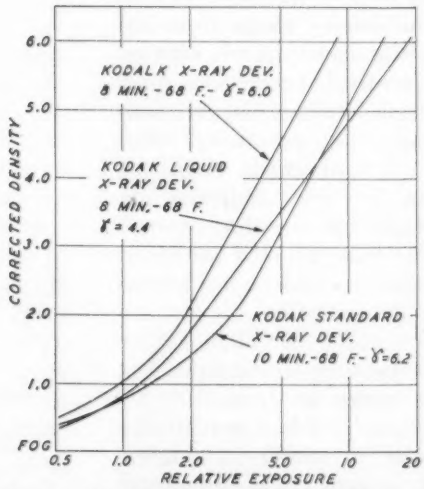


Fig. 9.—H & D Characteristics of Type A Film Processed in Three Developers to Obtain Optimum Results.

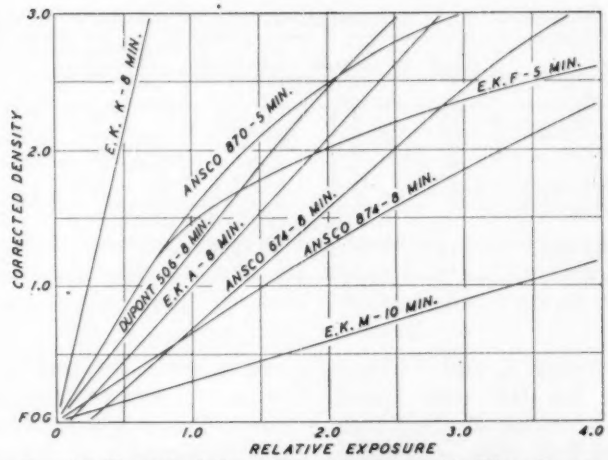


Fig. 10.—Low Density Characteristics of Eight Radiographic Films Developed in Kodalk. The linear slopes can be considered as a measure of the film speed.

Families of H & D characteristic (density *versus* log exposure) curves obtained from these emulsions exposed to 2-million-volt radiation are given in Figs. 1 to 8. All development times were converted into the corresponding time at 68 F., according to the processing chart for Kodalk X-ray developer. It was assumed that the development time-temperature response of the other films is approximately the same as that for the Eastman films for the temperature range involved (65 to 70 F.). Any differences in the slopes of the temperature-log time curves of the other films should not change the characteristic curves appreciably, especially since the majority of films were developed to completion to obtain the highest contrast and speed. Kodalk X-ray developer was chosen for this investigation because it yielded the highest gamma and speed on Eastman type A film, the emulsion which was most commonly used for radiographic work at the High Voltage Laboratory.[6] Three Eastman X-ray developers, Kodalk, Liquid, and Standard (D-19b), were investigated in connection with their effect on type A film. Three families of H & D curves were obtained in the manner as described above using radium gamma radiation. The optimum curves for each of these developers are shown in Fig. 9.

[6] During the war, the High Voltage Laboratory found that Eastman Kodak products were more readily available than were similar materials from other manufacturers. Consequently, most of the sensitometric experience of this laboratory is based on Eastman films. The reference to the products of this manufacturer is not to be construed as a preference, therefore, but as an example.

Standard X-ray developer was found to be slower in developing action than Kodalk. To obtain the same gamma on type A as attainable in Kodalk, a developing time of 10 min. (68 F.), as compared with 5 min., is required. The 8-min. Kodalk curve yields a significant density of 1.0 with an exposure less by a factor of 1.45 than that for type A developed in Standard. Because of the difference in the shapes of the two H & D curves, this factor increases to 1.75 for a density of 2.0. In Liquid X-ray developer, type A film does not reach so high a value of gamma as it does in Kodalk, the maximum value being 4.5, as compared with 6.2. For a density of 1.0 the exposure must be increased by 25 per cent in the case of the Liquid X-ray developer over that required when Kodalk is used.

The optimum development time for the films in Figs. 1 to 8 (indicated by the heavy curve) was determined by considering several factors, among which are (*a*) maximum gamma, to obtain the best sensitivity practicable; (*b*) fog density at optimum developing time; and (*c*) maximum film speed obtainable by prolonged development, to reduce radiographic exposures by darkroom manipulation.

For Eastman type F and Ansco Industrial No. 870, maximum gamma is attained after development for 5 min. at 68 F. Further development increases the speed of type F slightly but causes a more noticeable fog. In the case of Industrial No. 870, the maximum speed is obtained after 5 min., further development causing merely an increase in fog. For these films, therefore, 5-min. development appears best.

Although the maximum gamma of Eastman type K film is not reached after 8-min. development, the fog density obtained by immersion beyond this time is great. Thus, 8-min. development appears to be the best compromise between maximum gamma and tolerable fog density.

The maximum gamma of the other five films investigated is reached after development for 5 min. or less. There is, however, an advantage in developing for longer periods because of the increase in significant density. This density increase is an effective gain in film speed and allows shorter radiographic exposures to be made. In the case of type A film, for example, increasing the developing time from 5 to 8 min. results in a reduction of exposure time for the same density by a factor of 1.35. For radiography of thick sections, this reduced exposure time is important, and the fog density accompanying this longer development time is not objectionable. There is little to be gained, however, in developing for periods longer than 8 min. The superposition of the 7.5- and 10-min. curves for du Pont No. 506 film illustrates that any increase in density is merely an increase in fog rather than an intensification of the image. This fact shows up more graphically when corrected densities are plotted instead of total densities. Eastman type M film, however, can be advantageously developed for at least 10 min. without excessive fog. A gain in effective speed of about 30 per cent over 8-min. development is obtainable. For Eastman type A, Ansco Superay A and Superay B, and du Pont No. 506 films, therefore, 8-min. development in Kodalk developer seems best. For Eastman type M film, development to 10 min. is suggested to enable its use to be extended to thicker sections.

To compare the speeds of the various films, a linear plot of corrected density *versus* exposure was made. Figure 10 is such a graph for the eight films developed for

their optimum times in Kodalk X-ray developer. As can be seen, these curves are approximately straight lines up to densities of at least 1.2. The slopes of these curves can be considered as a measure of the speed. Films possessing a steep slope (the gain in density per unit increase in exposure being high) are faster radiographically than films having a lesser slope. The speed values given in Table I were obtained by multiplying the slopes of the curves in Fig. 9 by a suitable constant such that the speed of Eastman type A film = 100. Despite the fact that some radiographic films, such as Eastman type F and Ansco Industrial No. 870, do not exhibit this linear behavior beyond a density of 1.2, this method of speed evaluation is still of value because it establishes the density of the thickest portion of the object under investigation. Thinner sections will be recorded in a manner which depends on the characteristics of the film type.

The latitude of radiographic films may for certain purposes be defined as the ratio of the exposure to obtain a net density of 3.0 above fog to the exposure for a net density of 0.4. This density range represents the maximum useful region observable on an ordinary fluorescent-type viewer. The density of 0.4 was chosen as the lower limit primarily because the scattering of 2-million-volt radiation is such that significant radiographic recording can be made at smaller densities than at lower voltages. For example, a sensitivity of approximately 2 per cent is obtainable through 5 in. of steel on type A film at a density of 0.4 with 2-million-volt radiation. By using techniques to reduce scattering, this density can be made slightly less. Although there are many other ways in which latitude can be defined, this method serves to compare the ranges of the films.

In Table I, the films have been grouped together according to their characteristics. All development times are for Kodalk X-ray developer at 68 F.

TABLE I.

	Film Type	Speed	Gamma	Latitude	Developing Time, min.	Grain
	Group I					
a.	Type K	386	4.8	8.5	8	Coarse
b.	duPont 506	117	6.4	6.5	8	Fine
	Type A	100	6.0	6.1	8	Fine
c.	Super A	81	5.2	5.5	8	Fine
	Super B	60	7.8	9.0	8	Very fine
	Type M	28	7.2	7.5	10	Very fine
	Group II					
a.	Industrial No. 807	143	3.0	12.0	5	Medium
	Type F	143	1.8	43.0	5	Medium

Conclusions and Discussion

For radiography at 2-million volts, films such as Eastman type A, Ansco Superay A, and du Pont Fine Grain No. 506 were found most useful, because of their high contrast and fine grain, combined with speeds which permit radiography of steel sections up to about 12 in. thick without excessive exposure times. The exposure-thickness technique curves for 1- and 2-million volts d-c. given in Fig. 11 are for Eastman type A film exposed at 24-in. target-to-film distance for a density of 1.0 when developed 8 min. at 68 F. in Kodalk X-ray developer. With a correction of about 20 per cent, these curves can be used with Ansco Superay A or du Pont No. 506 films.

Although the characteristics of Eastman type K film are not so well adapted for general work because of lower contrast and coarse grain, this emulsion serves well in the radiography of very thick sections because of its high speed (about four times that of type A). In the region of thinner sections (up to 6 to 8 in. of steel) or when used with faster films in the same cassette (to increase the latitude for a particular exposure) Eastman type M and Ansco Superay B films are valuable because of their very fine grain and high contrast, allowing radiographs with best sensitivity to be made. In general, Eastman type F and Ansco Industrial No. 870 films were not used to any extent in this laboratory at 2-million volts because of their low contrast.

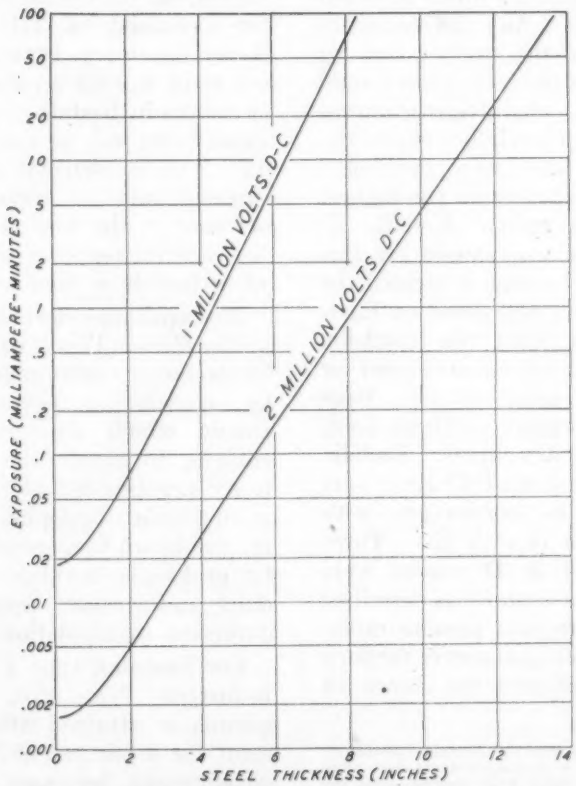


Fig. 11.—Exposure-Thickness Curves for Type A Film.
These exposures are for a target-film distance of 24 in. and for a net density of 1.0 when developed in Kodalk 8 min. at 68 F. Inherent target filtration is equivalent to 0.7 in. of steel.

These film characteristics curves are reproducible if processing conditions are maintained reasonably constant. As an example of its dependability, type A film was frequently exposed beneath a standard test block of 2 in. of steel at a fixed target-to-film distance to check the calibration of the generating voltmeter of the 2-million-volt electrostatic generators used in this investigation. By measuring the density obtained and comparing it with that predicted by the exposure-thickness chart in Fig. 11, the voltage could be checked within 10 per cent. Although more precise methods of calibrating the voltage were normally employed (accurate to within 0.1 per cent), the film check was quite reliable, especially when the exponential variation of radiographic exposure with voltage is considered.

Acknowledgments:

The authors wish to express their thanks to the staff of the High Voltage Laboratory for their assistance. In particular, we are grateful to R. J. Van de Graaff for his interest and advice; to A. Sperduto for his aid in obtaining the data for this paper; and to E. N. Strait, Jr., for his preliminary measurements on the sensitometric response of radiographic emulsions.

Discussion of the Practical Application of the Van de Graaff Electrostatic X-Ray Generator*

By D. T. O'Connor[1]

THE principles involved in the generation of high voltages by electrostatic means were published by R. J. Van de Graaff in 1933. The production and preliminary investigation of two-million volt electrostatic (MeV) X-rays were accomplished at the Massachusetts Institute of Technology in 1937 under his direction. In 1941 the Office of Scientific Research and Development National Defense Research Committee acting particularly for the Navy, contracted with M.I.T. for further development and eventually for the production of five 2 MeV X-ray generators.

The Navy Bureau of Ordnance X-ray program was originated and guided by C. S. Piggot, Section Chief of Re7. Under his direction two electrostatic generators were installed at the Ordnance Investigation Laboratory, Indian Head, Md. In the course of three years a fairly complete radiographic laboratory was built up around this nucleus.

The first generator, Fig. 1, was installed at the Ordnance Investigation Laboratory in 1943 and has been in constant use since. Because the machine is immovable it must be supported above the exposure room, and since the tank must be removed for generator repairs, there must be adequate headroom. Therefore, the building must be quite tall.

Fig. 1.—The First Generator Installed at Ordnance Investigation Laboratory in 1943.

Early in 1945 a second generator was installed, and other low-voltage radiographic equipment which had been temporarily housed was moved into a new complete radiographic laboratory (Fig. 2). The high-voltage section is, of course, on the far side. The exposure rooms are at the extreme ends of the building and radiation protection outside the building is obtained by fencing-in the area. The protection fence gates are visible in Fig. 2.

The generator in the new laboratory (Fig. 3) is mounted on a concrete deck and is almost noiseless. By disconnecting the tank-cooling water lines and removing the tank-base bolts, the tank may be raised very quickly and easily with a power hoist. On the left side is a mercury diffusion vacuum pump on which is mounted a McLeod Gage. In the background of Fig. 3 is a vacuum pump for removing the humid air from the

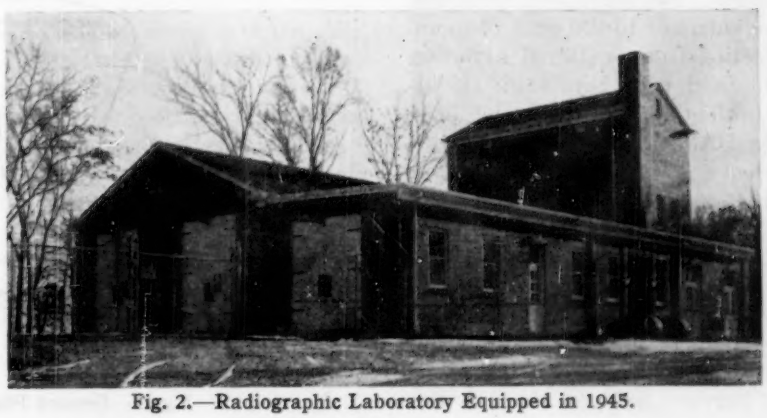


Fig. 2.—Radiographic Laboratory Equipped in 1945.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

* Presented at a Symposium on Ultra High Voltage Radiography sponsored jointly by A.S.T.M. Committee E-7 on Radiography and the American Industrial Radium and X-ray Society, held in Cleveland, Ohio, February 8, 1946.

[1] Naval Ordnance Laboratory, Naval Gun Factory, Washington, D. C.

[2] R. J. Van de Graaff, K. T. Compton, and L. C. Van Atta, *Phys. Rev.*, Vol. 43, p. 149 (1933).

Fig. 3.—Generator Mounted on Concrete Deck.

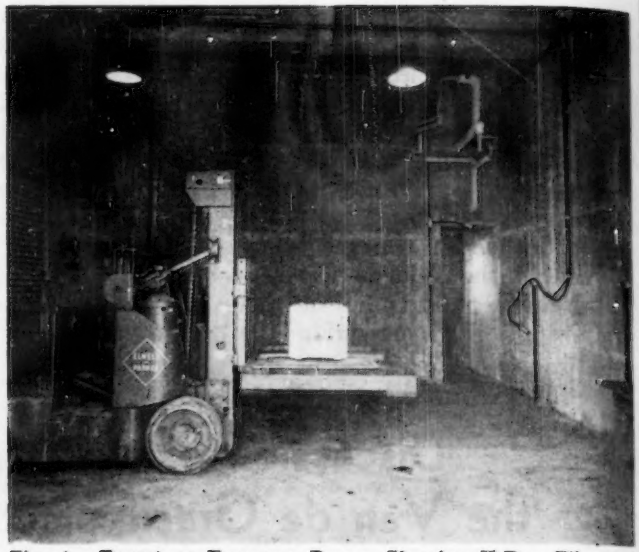


Fig. 4.—Target or Exposure Room, Showing X-Ray Film and Heavy Object Supported on Fork Platform.

Entrance to the control room is shown at rear right, with door and door frame protected by ¼-in. lead.

tank and to the right of it an air compressor and dryer which supplies dry air at 200-psi. pressure.

In addition to the vacuum pump and compressor on the second deck there are, to the right of the compressor, a relay cabinet, a distilled water-cooling system pump, and the magnetic lens battery rack.

The control room is small and contains only the control panel. Personnel in this room are completely protected by concrete and lead barriers.

Directly under the generator is the target or exposure room. As may be seen in Fig. 4, heavy objects are easily moved and positioned with industrial fork lift trucks. The interior walls in the background are reinforced concrete, 38 in. thick, and even without the 3-in. lead protective cone, no radiation has been detected through these walls. The passageway in the corner leads to a concrete labyrinth, the other end of which is the entrance to the control room. Protection from scattered radiation is obtained with ¼-in. lead, shielding both the door and the door frame. All doors are fitted with interlocks so that the opening of a target-room door will trip a relay and stop the production of X-rays.

The ground floor plan of the high-voltage end of the building is shown in Fig. 5. With the 3-in. lead cone in place no radiation can be detected through the concrete barriers or even through the 14-in. brick wall. A broken line indicates the irradiated area which is within the fenced-off portion of the grounds. The fence makes it possible to use inexpensive, light, wooden doors.

One of the most important considerations in regard to the Van de Graaff generator is the ease with which repairs may be made. The tank may be removed (Fig. 6) in about 10 min. by allowing the air to escape and removing the lower bolts. Removal of the high-voltage terminal exposes the pulley, filament generator, reactor, and filament assembly (Fig. 7):

In 1 hr. the entire column down to the base plate may be disassembled by two or three men. It may be completely reassembled and checked in 2 hr.

During the year January 1, 1945, to December 31, 1945—

Generator No. 1 was inoperative for 55 days:

28 days loss was due to tube trouble;
13 days loss was due to belt trouble;
14 days loss was due to miscellaneous causes, 6 days of which were due to building service failures.

Tube trouble was vacuum trouble; the installation of the sealed-off tube now completed and tested has eliminated loss of time due to this cause.

Research and development are being carried on at the present time by one of the engineering laboratories at M.I.T. which, we hope, and have reason to believe, will lead to marked improvement in belt performance.

To sum up last year's generator performance, the unit was in successful operation 77 per cent of the total number of work days. The 23 per cent loss, it is estimated,

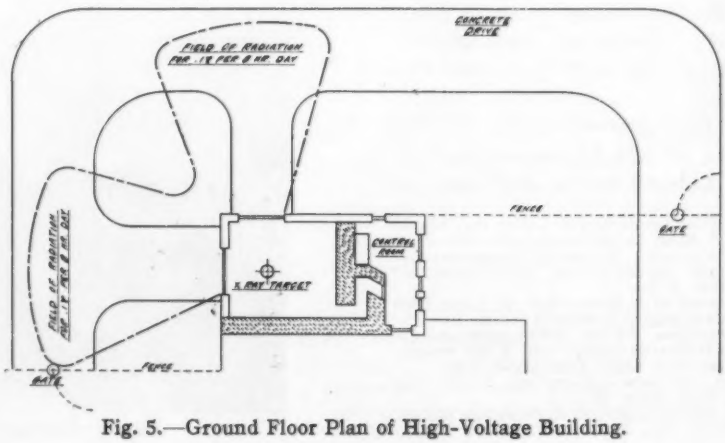


Fig. 5.—Ground Floor Plan of High-Voltage Building.

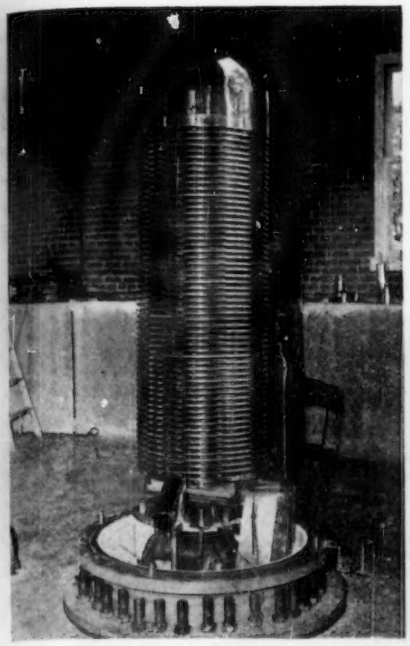


Fig. 6.—Generator Shown with Tank Removed.

can be reduced during the coming year by the use of the new sealed-off tubes and improved belts to approximately 5 per cent, a reasonable figure.

Our technique in the practice of 2MeV radiography is fairly well standardized. Since the X-ray beam is vertical and the generator rigidly mounted, the focal film distance which may vary from 3 to 12 ft. is controlled by industrial fork lift trucks. The film and object are supported on the fork platform (Fig. 4). Beneath the film holder is placed $\frac{1}{2}$ to 1 in. of lead which prevents back scatter and absorbs enough of the radiation transmitted through the object to decrease the room scatter appreciably. Above the film holder and beneath the object is placed a $\frac{1}{8}$-in. lead plate to absorb the object scatter.

Sensitivity is improved for thicknesses up to 4 in. of steel by lead thicknesses of approximately 0.080 in. No improvement has been noted for up to $\frac{1}{8}$-in. lead filter except for thicknesses from 4 to 10 in. of steel. For filter thicknesses of $\frac{1}{8}$ to $\frac{1}{4}$ in. of lead there is no improvement at any object thickness but there is an appreciable attentuation of the beam. Therefore, for almost all work, a $\frac{1}{8}$-in. lead filter is standard.

The generators have been operated at 2.5 MeV for limited periods of time with considerable success. However, this is not routine. Intensity ratio of 2.5 to 2 MeV is approximately 5 to 1 through 10 in. of steel.

The greatest thickness of steel we have penetrated is 15 in., through the base plate of the British 15-in. projectile. The greatest over-all thickness penetrated was $4\frac{1}{2}$ ft. of steel and explosive equivalent to about 10 in. of steel, through the center of a 4400-lb.

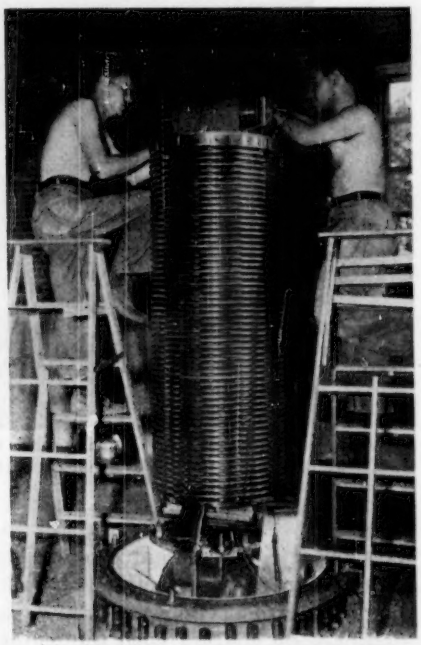


Fig. 7.—After Removal of the High-Voltage Terminal, the Pulley, Filament Generator, Reactor, and Filament Assembly Are Exposed.

experimental bomb. Cavities of considerable size were located.

One of the more interesting projects assigned to the laboratory was the inspection of American base fuzes in fired projectiles varying in size from 6 to 16 in., to determine whether the fuze had functioned properly. The explosives cavities had been loaded with an inert filler, iron oxide; the fuzes, however, were live before firing. Figure 8 shows the explosive cavity of a 6-in. armor-piercing projectile after having been fired through 6 in. of armor plate.

The fuze has been dislodged but shows evidence of having functioned. The twin boosters, one on each side, have fired as may be seen by the enlarged cavities which are superimposed in this shot. The booster protector ring of aluminum has been blown away and may be seen near the fuze base.

In the projectile shown in Fig. 9, the boosters have blown with low order detonations. The cavities are not much enlarged and though the booster protector ring shows evidence of disturbance, it has not been blown away.

Figures 8 and 9 show reproductions of radiographs of 6-in. projectiles. Figure 9 is enlarged two times over Fig. 8. This relative enlargement was obtained not photographically but by projection of the X-ray image. The projectile was positioned 3 ft. from the X-ray target, but the film, instead of being placed in contact with it as was the case in Fig. 8, was placed 6 ft. from the target. A projection of this kind is possible only when the source of X-rays is confined to an essentially pin-point spot. The very small focal spot size, 0.010 to 0.020 in., makes projections of this kind possible with the Van de Graaff generator.

The advantage of the small focal

Fig. 8.—Radiograph of the Explosive Cavity of a 6-in. Armor-Piercing Projectile After Having Been Fired Through 6 in. of Armor Plate.

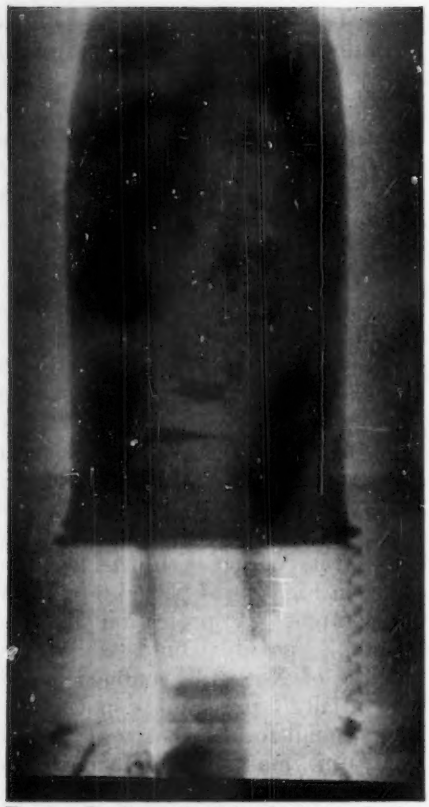


Fig. 9.—Radiograph of the Explosive Cavity of a 6-in. Armor-Piercing Projectile After Having Been Fired Through 6 in. of Armor Plate.

This reproduction is enlarged two times over Fig. 8, by means of projection of the X-ray image.

spot is not so much in the ability to make such projections which, after all, can be duplicated photographically, but in the ability to show on the film the detail on the tube side of a thick object with the same clarity as the detail on the film side of the object.

One very large field of work during the last three years has been the application of high-voltage X-rays to the inspection of large explosive castings. Figure 10 (*a*) shows one-sixth of an American depth bomb. A large horizontal cavity is revealed, running into the middle sixth of the bomb (Fig. 10 (*b*)) and extending all the way into the tail. Cavities of this nature were characteristic of a horizontal cooling technique which was standard practice. Depth bombs of this type were found to detonate on contact with the water when dropped above certain critical altitudes instead of exploding at a predetermined depth.

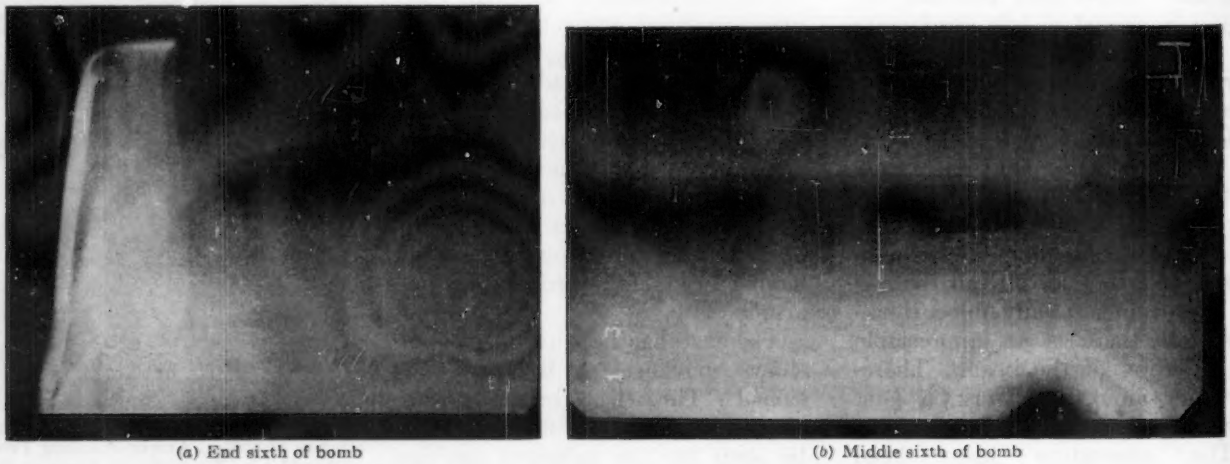
The pouring and cooling techniques were revised and the cavity located entirely in the after part of the bomb (Fig. 11). This simple change eliminated the difficulty, although not the presence of a cavity.

When new types of explosives and explosive mixtures are devised or loading procedures altered, the final results are now examined radiographically for soundness. All experimental charges are inspected to insure validity of results.

Fig. 11.—Revision of the Pouring and Cooling Techniques Resulted in Locating the Cavity in the After Part of the Bomb.

Since the loading of this bomb, much work has been done on explosive casts and loading techniques. It is extremely unusual to discover a cavity of any size in currently loaded ordnance.

At the time of the last great German counteroffensive, the Allied shortage of heavy artillery ammunition was well known. At least two disastrous cases of premature explosions of artillery shells in the



(*a*) End sixth of bomb (*b*) Middle sixth of bomb

Fig. 10.—Large Horizontal Cavity Revealed in an American Depth Bomb.

field had convinced the U. S. Army of the necessity for careful inspection of such ordnance.

The cause of premature shell explosions has never been accurately determined, but enough evidence existed to indicate that a faulty explosive casting could cause it; furthermore, no shell of known internal soundness had exploded prematurely. At that time the radiographic facilities of the U. S. Army were overtaxed and the Bureau of Ordnance was asked to examine two carloads of large caliber shells. The examination was completed in eleven 18-hr. days. Six hours were required each day to recharge the industrial truck and lens batteries.

From the very beginning of the Bureau X-ray program, enemy ordnance equipment was examined by means of radiography. The Navy was required to disassemble or strip many thousands of captured explosive items for chemical analysis, operational analysis, or to provide samples of enemy ordnance for instructional purposes. The hazards of the stripping operation were reduced to zero by means of radiography; danger points were plainly visible on the films; physical construction was easily discovered and the stripping operation became a simple mechanical problem with no unknown factors.

Very frequently complete operational analysis could be made from the film alone.

Radiographs were particularly valuable in the case of magnetic and acoustic mine units and Rheinmetal fuzes where complete disassembly was often impossible due to fineness of construction and the generous use of pitch. Such fuze bodies when the condenser circuits were complete were pitch-filled and extremely difficult to analyze without recourse to radiography.

The Bureau of Ordnance has applied high-voltage radiography not only to the investigation of foreign ordnance but to its own weapons and has succeeded in a great many cases in increasing both the safety and effectiveness of U. S. ordnance by knowledge obtained through radiography.

Introduction to Statistics*

By A. E. R. Westman[1]

I DEEM it an honor and a privilege to have been asked as a member of Committee E-11 on Quality Control of Materials to introduce the subject of statistics at this Symposium on Paint and Paint Materials.* I know from the titles of the papers which follow, and from other papers that have appeared in the protective coating literature, that this subject needs no introduction to many of you and my remarks will be largely for the benefit of those who are meeting the subject of statistics for the first time or who, having had a few contacts with it, are wondering what justification there is for this bristling mouthful of seven consonants and three vowels in A.S.T.M. work; are inclined to distrust the apparently rubbery sort of reasoning that is involved; are perhaps a bit dismayed at the prospect of having to learn a new jargon and a new kind of arithmetic; and are hoping, perhaps unconsciously, that this madness that infects men's minds will shortly be eliminated by some hard-boiled realistic thinking on the subject.

I hope to show you that the statistical approach *is* a hard-boiled, realistic approach, and that it is in the best scientific and engineering tradition in that it faces facts, insists on measuring the quantities with which it is concerned, and above all, reasons quantitatively rather than qualitatively.

Prediction:

First, let me point out that the object of nearly all scientific and engineering study is *prediction;* which is a polite term for foretelling the future, and our A.S.T.M. work is no exception. This does not mean that we spend our time looking dreamily into a crystal ball, but does mean that we are concerned with projecting our experience, quantitatively, into the future. We want to know how a raw material will behave under service conditions, how a test method will work out in practice, how long a paint job will last or what percentage of customer complaints we may xpect with a certain varnish formulation.

For this reason, I believe I can introduce the subject of statistics best by comparing two simple problems in prediction, one of which will fit in with the older training and experience, the other being essentially sta'istical in character.

Traditional Example:

I am sure that you have all heard of or have actually used Johansson blocks. They are extremely accurate metal blocks which are used as standards in most gaging work and although a physicist used to chopping up light waves may point out that there is a limit to their accuracy, and a philosopher may object that even our concept of length may be illusory, I believe that as engineers and so far as ordinary machining operations are concerned, we may accept without question the statement that a 1-in. Johansson block or "Joe" block is exactly 1 in. in length.

My first problem in prediction is

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* This paper was presented at the Symposium on Paint and Paint Materials, held at the 1947 Spring Meeting of the Society in Philadelphia, February 25, 1947. It also appears in the Symposium on Paint and Paint Materials, issued as a separate publication, along with the other two papers on statistics presented at that symposium.

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this. If you take a 1-in. Joe block and a 2-in. Joe block and "wring" them together in the approved fashion, what will be the over-all length of the assembly? The traditional answer is, of course, that 1 plus 2 equals 3 and, therefore, the assembly will be 3 in. long. Now, this kind of "Joe block" prediction is exactly what most engineers and scientists have been trained to do. It has certain characteristics which are worth noting. It starts from certainties and it admits no possibility of failure. No matter where the Joe blocks come from or how often we make the above prediction, we shall always be right. In other words, we can predict the outcome of individual experiments with certainty.

This kind of "Joe block" reasoning would be quite adequate and very comforting if we lived in a "Joe block" world where all machine parts were made with "Joe block" accuracy, where every shipment of a certain type of coal was exactly like all other shipments of the same coal, etc., but such a world is practically impossible of attainment and even if possible, would be uneconomic. If you have ever bought a set of "Joe blocks" you will vouch for that. If you find it not too hard to believe that every batch of your No. 129 white paint is exactly the same as every other batch, I would ask you if every shipment of linseed oil you receive is exactly the same, or if every customer applies your paint in exactly the same way and subjects it to exactly the same weathering conditions.

Statistical Example:

Let us contrast the above problem in prediction with one in which two automatic machines are turning out a steady production of two piece-parts, the one nominally 1 in. in length and the other nominally 2 in. in length. When these parts are assembled end to end in groups of two, what will be their over-all length? Since such machines do not operate with "Joe block" precision, each machine introducing some variation, we are at once faced with a difficulty. The "Joe block" reasoning no longer applies. We can try to escape by saying that the assemblies will be "nominally" 3 in. in length but, unfortunately again, we do not live in a "nominal" world and the performance of the assembly in point of fact will not depend on its "nominal" length. I recall during the late war some badly needed military trucks rolling off the production line and then seizing up before they had been driven fifty miles because the "nominal" clearance between piston and cylinder, which was counted on to see them through the breaking-in period, in point of fact hardly existed.

One of the first things we miss in this second type of problem is the ability to predict individual assembly lengths. We can no longer say that no matter what assembly is selected, we can say exactly how long it will be, as we could with the "Joe blocks." We shall have to be satisfied with something less than this. But does inability to predict individual cases with certainty leave us completely helpless? If such were the case, I think a little reflection will convince you that life would be impossible. Throughout our lives we are continually making decisions in situations where it is impossible to be certain of the outcome. If we insisted on the "Joe block" kind of decision, we would be unable to cross a street, to order a meal, to get married, or to make any of the thousands of decisions we have to make. In fact, if this audience existed at all, it would now be jamming the doorway of this room unable to decide whether to come in or stay out.

Now, we make the great majority of such decisions in a rather qualitative way. We sort of mentally weigh up the probabilities in the situation and then go ahead for better or for worse. But this is not good enough for engineering or A.S.T.M. work and we would not be applying statistics to the above assembly problem if we did not look further into the situation, but merely made the best guess we could under the circumstances outlined.

Statistical Stability:

In applying statistics to the above problem we would insist, first, on satisfying ourselves that there is enough stability in the situation to warrant projecting our experience into the future, and, second, on *measuring* the *amount* of variation introduced by the machines. The first requirement is essential to any prediction. The second enables us to reason quantitatively. We would be foolish to commit ourselves with respect to any machine in advance, since it might be very erratic in its action. Nor do we, in practice, accept the accuracy which may be claimed for a particular machine, but we insist on measuring the characteristics of the product.

But, you may ask, is it possible to have a situation in which indi-

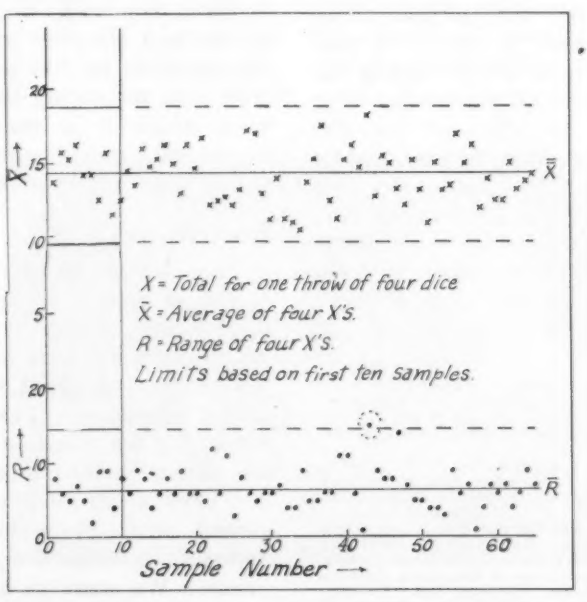

Fig. 1.—Control Charts Showing Statistical Stability of Dice Data.

vidual values are uncertain and yet have an inherent stability which allows prediction? And if it is, how can we satisfy ourselves that such is the case?

Figure 1 will illustrate just such a situation. Four dice were thrown repeatedly and the number of pips showing was recorded as the value of each throw. This value could range from 4 to 24. After 40 throws had been made, the values were grouped into 10 groups of 4 throws each and the average and range (highest minus lowest) for each of the ten groups plotted in chronological order starting at the left of Fig. 1, the range serving as a measure of variation. The control limits shown in full line were calculated by the methods given in the A.S.T.M. Manual on Presentation of Data[2] and were extended in broken line across the figure. These limits provide a test for stability, since under stable conditions only about three points in a thousand should fall outside the limits. The experiment was then continued until 260 throws had been made and the remaining points could be plotted as shown in the figure. It will be observed that all but one point fell within the limits.

Now, here clearly we have a case in which the individual result is unpredictable in the sense that we do not know with certainty in advance of a throw whether we will get 4 or 24 or some value in between and yet we have a statistical stability with respect to time both with regard to values we obtain and to the variation observed at different times. I think you will agree that as long as this stability holds we can predict the kind of distribution of values we will obtain and make quantitative calculations regarding their variability. Also, under these conditions, we can attach more reliability to average values calculated from the data because the random variations will tend to cancel out more completely.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 33, Part I, p. 453 (1933). (Also issued as separate publication.)

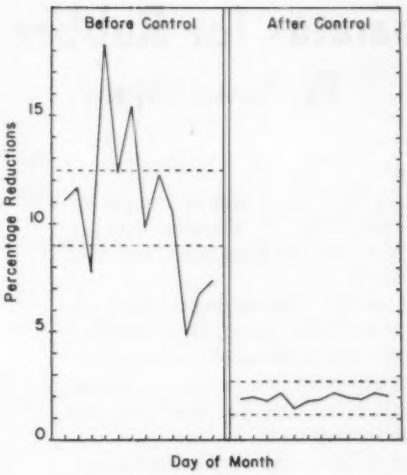

Fig. 2.—Control Charts Showing Statistical Stability Achieved in the Manufacture of Tank Shoes.

But, you may say, that kind of reasoning is all right with dice, but can you apply it to the machines you were talking about, or to batches of paint, or to exposure experiments? The best answer is probably given by the very large number of cases in the past twenty years or so when it has been found possible to make machines, manufacturing processes and physical and chemical tests exhibit the kind of control exhibited by the dice in the above experiment. Figure 2 will illustrate one of these.[3]

Conclusion:

To go farther into the subject would involve me in discussions out of place in introductory remarks such as these. I trust that I have made the point that statistical reasoning is realistic, sound, quantitative, and in the best engineering tradition; that a need for it exists in the world as we find it and particularly in A.S.T.M. work.

In the papers which follow, you will see examples of statistical reasoning which may not on the surface bear much relation to the simple examples I have discussed, but I believe you will see the same desire to face the facts, to avoid bias in comparisons, and to have any unavoidable variability enter into the experiment in such a way that its effects can be estimated quantitatively, and the risk of a wrong decision calculated.

[3] "Statistical Control of the Manufacture of Manganese Steel Tank Shoes," Canadian Metals and Metallurgical Industries, June, 1945.

Work of Committee E-11 and Relation to D-1

Before closing, I should like to refer to the work of Committee E-11 and to explain how Committee D-1 can cooperate in this work.

Committee E-11 is engaged in the following types of work:

1. The aiding and advising of technical committees of the A.S.T.M. in the application of statistical methods in their work.
2. The compiling of a Manual on Quality Control of Materials in which will be included a revision of the present Manual on Presentation of Data, and a number of sections giving basic information and standard procedures for applying statistical methods in A.S.T.M. work.
3. A study of the whole question of systems of sampling inspection and their relation to A.S.T.M. specifications and consumer-producer cooperation in A.S.T.M. activities.

Committee D-1 can assist in and derive the most benefit from the work of Committee E-11 by instructing one of its present subcommittees, or setting up a new subcommittee to maintain contact with E-11 and to act as a clearing house for D-1 matters related to any of the E-11 activities listed above. In addition, we should like to have D-1 members who have had experience in statistical methods made available to act as consulting members on the various task groups set up by E-11. Finally, there are many questions such as that implied in (3) above which may only be capable of solution in particular instances by the committee responsible for the specification proper, that is, by one of the D-1 committees as far as protective coatings are concerned.

Burst Test Apparatus for Rubber and Synthetics

By Austin Bryant[1]

SYNOPSIS

The burst test consists essentially of the bursting of test specimens by means of air pressure. Two test methods are employed; the instantaneous burst, which is comparable to a tension test, and the time burst, which is comparable to a long-time tension or creep test.

The burst test affords a very convenient method of measuring the strength of rubber and synthetic compounds. It is especially adaptable to measuring the effects of aging and measuring the strength at elevated temperatures.

There does not appear to be a very close correlation between bursting strength and tensile strength. However, it is felt that for many purposes the burst test is more significant than the tension test.

The burst test is limited in that it does not give any results comparable to the stress-strain relationship or to the ultimate elongation, nor does it afford any means of measuring the tear resistance. The time burst, however, gives a significant result which cannot easily be obtained in any other way.

Description of the test apparatus and its use together with a discussion of the results obtained are given.

THE burst test apparatus presented in this paper comprises special physical testing equipment developed by the author for rubber and synthetics and used by the Grove Regulator Co. for the past three years. This company manufactures various regulators and valves in which synthetic or natural rubber is employed in quite severe and unusual service. This testing equipment was developed in order to check easily the effect of various aging conditions on the strength of rubber and synthetic compounds and also to provide a quick check on the consistency of the material in factory run products.

The burst test consists essentially of the bursting of test specimens, usually small circular disks, by means of air pressure. These may be cut from test sheets or from the product itself.

Two test methods are employed, the instantaneous burst and the time burst. The instantaneous burst apparatus builds up pressure at a given rate and indicates the pressure at which the specimen bursts. The time burst apparatus holds a constant pressure on the specimen and records the length of time to burst.

Figure 1 shows a photograph of the complete apparatus. The cabinet on the left contains the time burst apparatus which comprises three separate time burst units (three test specimens may be run simultaneously). The cabinet on the right contains the instantaneous burst apparatus. Various specimen holders are shown on top of the cabinets.

SPECIMEN HOLDERS

Figure 2 is a drawing with tabular dimensions of the specimen holder used for ordinary disk specimens. It also shows cross-sections of the holder assembled with a specimen under conditions of no pressure, low pressure, and high pressure (just before bursting). This type of holder is used for most testing.

In certain cases special holders may be used. Figure 3 shows a holder designed to use sections cut from tubing as test specimens. It also illustrates the method of using a light wire and notched rod for inserting and removing the specimens. Under test the pressure forces the rubber out into the two V grooves near either end of the specimen, causing them to act as a clamp and seal.

INSTANTANEOUS BURST TEST APPARATUS

Figure 4 is a schematic diagram of the instantaneous burst test apparatus. The regulator holds a constant pressure of 2000 psi. as read on gage 1. The adjustable restriction limits the flow of air into the air chamber to give a definite rate of pressure increase on the specimen. With valves *B* and *C* closed, this restriction allows a pressure build up (read on gage 2) from zero to 500 psi. in 15 sec. when valve *A* is opened. The air chamber may be of any convenient size as long as it is large compared to the volume created by the de-

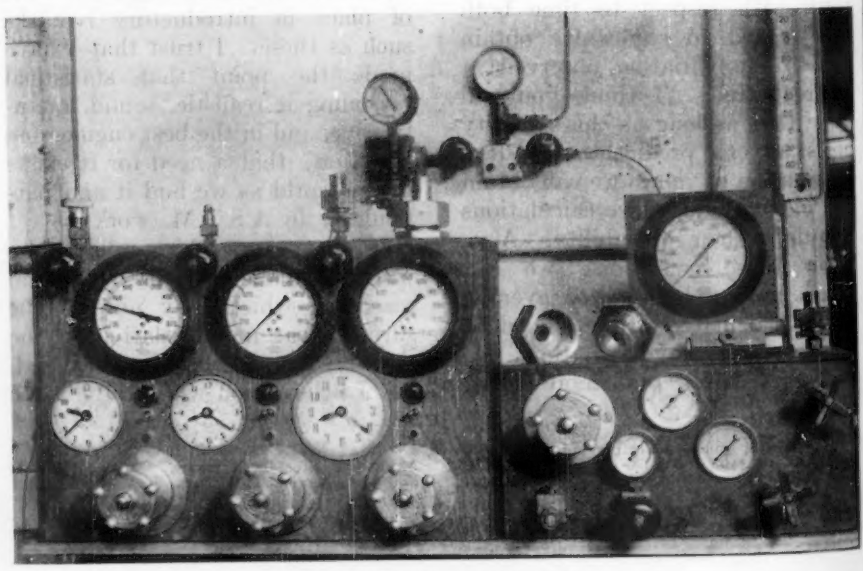

Fig. 1.—Burst Test Apparatus.

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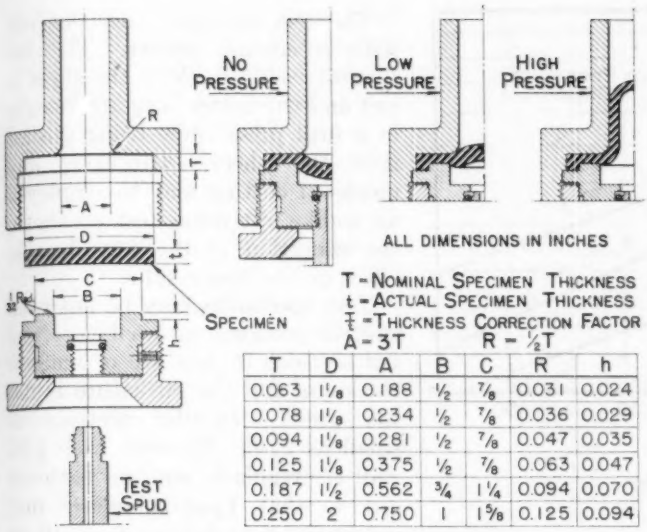

T	D	A	B	C	R	h
0.063	1⅛	0.188	½	⅞	0.031	0.024
0.078	1⅛	0.234	½	⅞	0.036	0.029
0.094	1⅛	0.281	½	⅞	0.047	0.035
0.125	1⅛	0.375	½	⅞	0.063	0.047
0.187	1½	0.562	¾	1¼	0.094	0.070
0.250	2	0.750	1	1⅜	0.125	0.094

Fig. 2.—Disk Specimen Holders.

flection of the specimen. It should not be so small as to make the restriction adjustment too critical, nor should it be so large as to give measurable pressure drop in the air-chamber connection. The air chamber in the apparatus shown contains about 6 cu. in. The check valve used was specially constructed for this apparatus and serves to trap air in the air chamber when the specimen bursts, thus giving an opportunity to read the bursting pressure on gage 2. It consists of a loose metal disk with a synthetic rubber face held closely below a nozzle. Gravity keeps the

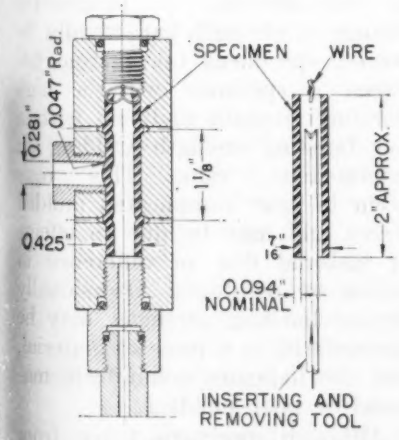

Fig. 3.—Special Tubing Specimen Holder.

check open (the disk away from the nozzle) so that there is no pressure differential between the specimen holder and the air chamber as the pressure builds up. When the specimen bursts, the disk suddenly flies up and closes the nozzle before a measurable loss of air occurs. Gage 3 serves as a check on the absence of pressure drop between the specimen holder and the air chamber.

The instantaneous burst test is performed in the following manner. Assuming that the regulator and adjustable restriction are properly adjusted and that valve *A*, Fig. 4, is closed and valves *B* and *C* open, a test specimen is mounted in its proper holder and the holder mounted on the test spud (protruding from top of cabinet on

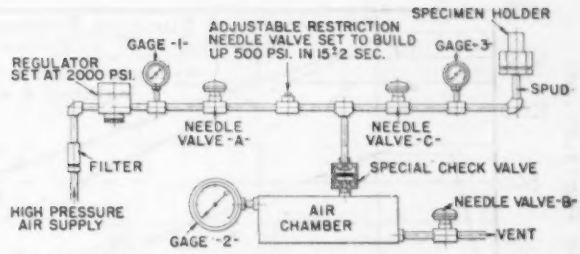

Fig. 4.—Schematic Diagram of Instantaneous Burst Test Apparatus.

right-hand end, Fig. 1). Valve *B* is then closed and valve *A* opened. Gage 2 is read as soon as the specimen bursts. This reading, when corrected by multiplying by the thickness correction factor, is the instantaneous bursting pressure (called bursting pressure) for the specimen. This correction is linear with the thickness as will be explained later.

Time Burst Test Apparatus

Figure 5 is a schematic diagram of one unit of the time burst apparatus. In this apparatus it is desired to hold a constant pressure very accurately for long periods of time. To eliminate the effects of supply pressure variation on the reduced pressure, two stages of reduction are used. The supply regulator is set to maintain a constant pressure (usually 1200 psi.) as read on the supply gage. This regulator (shown mounted on the

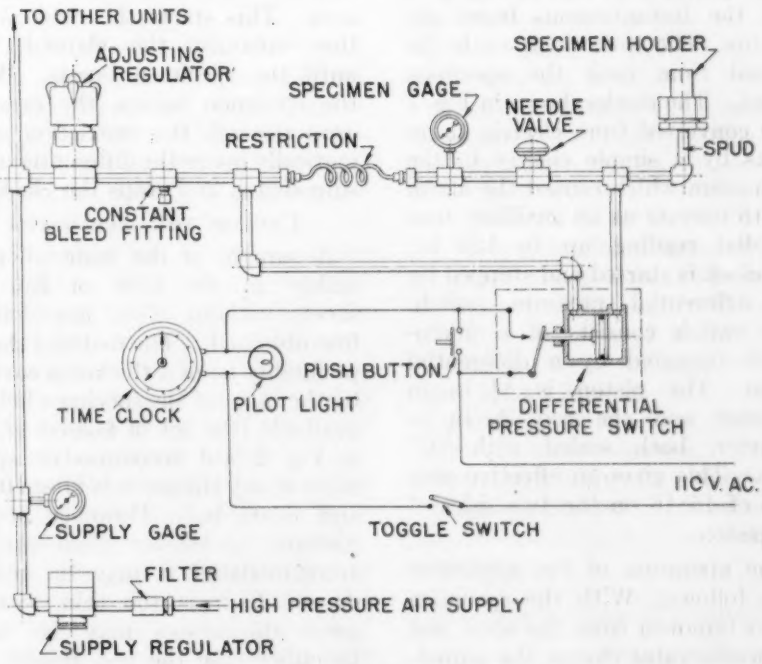

Fig. 5.—Schematic Diagram of Time Burst Apparatus.

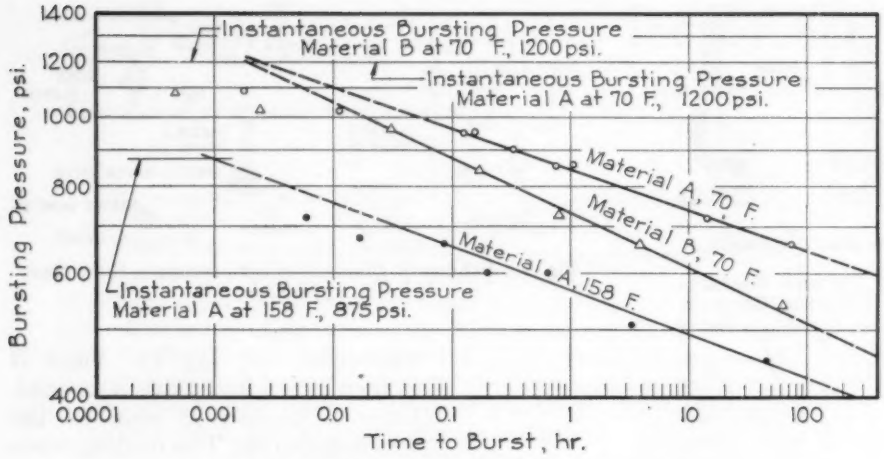

Fig. 6.—Typical Time Bursting-Pressure Curves.

wall in Fig. 1) supplies all three units of the time burst apparatus. The adjusting regulator is used to set the pressure which is to be maintained on the test specimen and is read on the specimen gage. The constant bleed fitting is set to bleed 50 to 100 cu. cm. of free air per minute to atmosphere (when pressure is 500 psi.), and is used to prevent the building up of pressure and to help maintain an absolutely constant pressure. The restriction, which consists of about 25 ft. of $\frac{3}{32}$-in. diameter (0.040-in. bore) copper tubing, limits the escape of air when the specimen bursts and also provides a pressure drop to operate the differential switch. The same specimen holders are used as with the instantaneous burst apparatus. The time clock reads the elapsed time until the specimen bursts. The clocks shown in Fig. 1 were converted from electric alarm clocks by a simple change in the mechanism which caused the alarm dial to operate as an auxiliary timing dial reading up to 120 hr. The clock is started and stopped by the differential pressure switch. This switch consists of a microswitch operated by a differential piston. The piston is $1\frac{1}{4}$ in. in diameter and the rod $\frac{5}{16}$ in. in diameter, both sealed with "O" rings. This gives an effective area ratio of 15:16 on the two sides of the piston.

The operation of the apparatus is as follows: With the specimen holder removed from the spud and the needle valve closed, the adjusting regulator is set at the required pressure. This pressure is the desired time-bursting pressure divided by the thickness correction factor. The needle valve is cracked and then closed again to make sure the setting is correct. The time clock is set to 12 o'clock and the toggle switch closed. The clock does not start because the pressure is holding the differential pressure switch open. If it is desired to make a very short-time test, the second hand may be reset by operating the clock with the push button switch. The specimen holder with the specimen is screwed on the spud and the needle valve opened. When the pressure on the specimen reaches $\frac{15}{16}$ of the set pressure, the differential pressure switch closes, due to its differential area. This starts the clock which then measures the elapsed time until the specimen bursts. When the specimen bursts, the pressure drop through the restriction automatically opens the differential pressure switch and stops the clock.

Use of the Apparatus

A sample of the material, preferably in the form of flat test sheets without cloth insertion, is first obtained. The material should preferably be of a thickness covered by the range of the specimen holders available (the set of holders shown in Fig. 2 will accommodate specimens of any thickness between 0.050 and 0.300 in.). However, if the material is thicker than can be accommodated it may be ground down. If it is too thin, two or more thicknesses may be used. In either case the test results will not be very seriously affected.

The test specimens are cut out with a circular cutter. The cut is most easily made if the sheet is wet and the cutter is rotated slowly in a drill press while being pushed into the sheet. However, any means of cutting may be employed as, unlike a tension test specimen, the condition of the edge has no effect on the test results.

Test specimens may be cut from curved sections as well as from flat sections if they are of uniform thickness and the curvature is not too great. Tubular sections as small as $2\frac{1}{8}$-in. diameter with $\frac{1}{8}$-in. wall are regularly cut and flattened out so that $1\frac{1}{8}$-in. diameter disk specimens may be cut from them. These specimens show no measurable difference in bursting pressure whether placed in the holder concave up or concave down.

Two or more specimens are first tested on the instantaneous burst apparatus. Time bursts are then run on other specimens from the sample at various pressures below the instantaneous bursting pressure. The results may be plotted on log paper as illustrated by Fig. 6.

The instantaneous burst test gives very consistent results in that the bursting pressure of various specimens cut from the same piece will usually not show more than 2 per cent total variation between the highest and the lowest. Where a greater variation (say 5 per cent) is encountered, a progressive change in strength can usually be traced, specimens taken from between a specimen with a high bursting strength and one with a low bursting strength yielding an intermediate value. This may occur in more complicated molded pieces and may be due to effects of material flow or difference in curing temperatures. Occasionally erratic bursting strength may be encountered in a piece of material, but this indicates nonuniform material or poor molding.

Although specimens taken from any one piece of material (especially from a test sheet) will show very uniform results, there may be considerable variation between one piece and another even when molded at the same time from the same lot of material (probably due to cure). For this reason instantaneous burst

tests should be run on each sheet from which time burst specimens are to be taken. For the same reason, instantaneous burst tests (in the "as-received" condition) should be run on all test sheets from which specimens for aging are to be taken.

The burst test is a very convenient method of determining the effects of aging (either in solvents or at elevated temperatures, or both) on the physical strength of a material. The test specimens (usually $1\frac{1}{8}$-in. diameter and $\frac{1}{8}$ or $\frac{3}{32}$ in. thick) used for this purpose are of a convenient size and shape and a large number can be obtained from a relatively small amount of material.

A number of specimens are aged together. A convenient method of separating the specimens to allow free contact of fluid, and at the same time keeping them in order, is to place them between the coils of a light closely coiled spring. A spring $\frac{7}{8}$ in. in diameter wound from 0.030-in. diameter wire and having 20 or 30 turns is a convenient size. Two or three coils are allowed between specimens.

Two or three specimens are used to measure the swell (or shrinkage) at intervals while the others are kept to run burst tests at periodic intervals. Time burst tests may also be run at certain intervals; for example, after 30 and 90 days.

One point in favor of the burst test is the convenience with which the strength at elevated temperatures may be determined. A test spud may be mounted in an oven (which may be at a considerable distance) and connected to the burst test apparatus by means of copper tubing. Such a connection is shown leading from the left-hand unit in Fig. 1

Control Check Tests

One of the principal uses of the burst test is the control of the quality of factory run products. For each material the minimum allowable values for both the instantaneous bursting pressure and for the time bursting pressure which will hold for 4 hr. are determined. The required time bursting pressure is given as a percentage of the measured instantaneous bursting pressure. However, a definite minimum is often also specified.

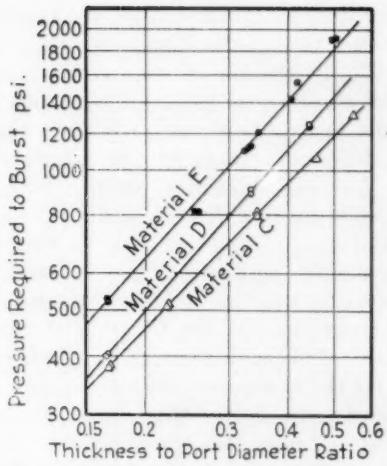

Fig. 7.—Relation Between Pressure and Thickness to Port Diameter Ratio.

Two specimens are cut from a test sample (either a special test sheet or one of the products) and the bursting pressure determined. If the results, after correcting for thickness, check within 5 per cent and are over the minimum allowed they are averaged and the required time bursting pressure determined.

Another specimen is taken, the thickness measured, and the gage pressure to give the required corrected time bursting pressure is determined. The specimen is then tested at this pressure on the time burst apparatus and if it lasts over 4 hr. the material is deemed satisfactory from a time burst standpoint.

Choice of Dimensions

The specimen thickness to port diameter ratio was chosen as $\frac{1}{3}$ because this was roughly equivalent to the service to which most of the material to be tested is normally subjected, and this ratio gave a bursting pressure which was easily obtainable. However, using this ratio many materials have a bursting strength in excess of 1000 psi. This pressure may be difficult to obtain in some laboratories and a lower thickness to port diameter ratio may be more convenient.

The rate of pressure buildup employed in the instantaneous burst test was chosen rather arbitrarily. It was felt that if the buildup was faster some materials would not have time to flex and burst and if it was slower an excessive time would be required to make the test. For ordinary materials the change in bursting pressure caused by variations from the chosen rate of buildup is very small and hence this adjustment is not critical. Tests have shown that for ordinary synthetic rubber a variation in the rate of pressure buildup of 30 per cent will cause an error of only $\frac{1}{4}$ to $\frac{1}{2}$ per cent in the bursting pressure. This is below the normal accuracy of measurement.

Thickness Correction Factor

Tests on various synthetic rubbers using specimen thickness to port diameter ratios between $\frac{1}{8}$ and $\frac{1}{2}$ show that the pressure required to burst a specimen in some cases varies nearly proportionally to the thickness to port diameter ratio while in other cases it may vary by as much as the 1.15 power of this ratio. Figure 7 shows this relation for three different synthetic rubber compounds. The test specimens for each curve shown in Fig. 7 were taken from a single piece of material. The test specimens for materials C and D were cut from test sheets approximately $\frac{1}{8}$ in. thick while the test specimens for material E were cut from a test sheet approximately $\frac{3}{32}$ in. thick. These specimens were tested on the instantaneous burst apparatus using the various sizes of holder shown in Fig. 2.

If a specimen of a certain thickness is burst in the holder for the nearest nominal thickness, sufficient accuracy is obtained by using the ratio of nominal to actual specimen thickness for the bursting pressure thickness correction factor.

Effect of Lamination

When a specimen is too thin to fit any of the holders available, two or more specimens may be placed together and tested as a thicker specimen. Tests on some materials have shown 5 or 10 per cent lower bursting pressure where two specimens are tested together. This difference may either be corrected for or the uncorrected pressure used in comparison with tests on other thin specimens.

Comparison with Tension Test

It would appear that a conversion could be obtained between tensile

strength and bursting pressure, involving the Shore durometer hardness. However, as yet no good correlation has been obtained. In general, for a given tensile strength the bursting strength appears to increase with increasing durometer hardness.

The author feels that in many cases, especially where the material is to be used under pressure for diaphragms or similar applications, the burst test is a more significant test than the standard tension test.

Limitations of Burst Test

One of the limitations of the burst test as compared to the tension test is that it does not give the equivalent of the stress-strain relationship or the ultimate elongation. Some work has been done along this line but no very satisfactory method has been developed as yet. When the specimen is clamped in the holder (see Fig. 2) a considerable bulge is formed. This varies with the amount of clamping, which in turn varies with the specimen thickness. The tightness of clamping appears to have a negligible effect on the bursting pressure but does have an effect on the deformation.

The problem of obtaining test results equivalent to the stress-strain relationship and the ultimate elongation not only involves devising a suitable means of measuring the deformation as a function of pressure but probably also the design of a different type of specimen holder.

Another limitation of the burst test is its inability to indicate tear resistance. Also the tear resistance probably influences the bursting pressure less than it does the tensile strength as measured in the tension test. This may account for the fact that the burst test gives much more consistent results than the tension test and may also partly account for the lack of correlation between the two.

The Time Bursting Pressure Curve

One significant result (having no equivalent in ordinary tension testing) obtained from the burst test is the time bursting pressure curve. If the time bursting pressure is plotted against bursting time on log paper, it has been found that the points for time greater than 1 min. or 0.02 hr. will fall on a straight, or nearly straight, line. The slope of this curve should then give an indication of the ability of the material to withstand a sustained load.

Typical time bursting pressure curves for two synthetic materials are shown in Fig. 6. These two compounds were chosen to illustrate the time bursting pressure curve as they have identical instantaneous bursting pressures but their time bursting pressure curves, taken at 70 F., differ considerably. It is fairly obvious that material B would sustain considerably less load than material A. Both of these compounds are made from the same base stock, Hycar O.R. 15, and have the same hardness, 65 Shore durometer A.

A time bursting pressure curve is also shown, in Fig. 6, for material A taken at 158 F. In this particular case the curve taken at 158 F. has nearly the same slope as that taken at 70 F. but is considerably lower. Time bursting pressure curves taken at elevated temperatures may show either greater or less slope than those taken at normal temperatures.

It is impractical to plot the time bursting pressure curve on ordinary log paper having equal cycle lengths in each direction. Special log sheets were made up having seven cycles for the time scale, from 0.0001 to 1000 hr., and one cycle for the pressure scale, from 200 to 2000 psi. The curves may be plotted on semi-log paper but the lines are not straight and the results are not nearly so significant.

Metals and Plastics

Metals and Plastics (*Production and Processing*) by Thomas P. Hughes of the University of Minnesota is an introductory textbook in the field of materials testing and production. The treatment of the material in this book is elementary, and no attempt is made to introduce any new or controversial material.

The first three chapters of the book deal with metals and their internal structures, equilibrium diagrams and the physical properties of metals. In these chapter there is a short history of the use of metal and definitions of the various properties of metals, a discussion on the mechanism of the solidification of metals, and a description of compounds, mixtures, and solid solutions. Then follows an introduction to equilibrium diagrams, and a description of the various types of such diagrams, including the method for the calculation of phases. This is followed by a listing of the mechanical properties of metals, and a description of the test methods.

The next five chapters deal with the manufacturing processes employed in the production of metals and include the manufacturing of iron, casting processes, ferrous castings, manufacturing of wrought steels, and non-ferrous metals and alloys.

The next two chapters are concerned with the iron-iron carbide diagram and the heat treatment of steels. The first chapter contains a discussion of the changes which make the heat treatment of steel possible, and the second chapter describes the heat-treating methods in use today. The next chapter covers the mechanical working of metals and the equipment used for these processes. The next two chapters discuss the welding and brazing of metals, and contain a description of most of such joining methods in use.

There is one chapter devoted to plastics which covers their processes and uses. The last chapter contains a classification of steels, and is followed by an appendix containing definitions of the terms used in the text and tables of the properties of various metals.

As stated above, this book is primarily an elementary textbook on the subject of metals and plastics. There is much useful information contained in it, and it should serve as an introduction to the subject for those who intend to study any one or all of the fields much further. It would also serve to give a superficial knowledge of the subject to one whose chief interests were elsewhere. For those who do wish to follow up any of the subjects covered, each chapter contains a good list of references.

The book's chief weakness is that it hardly lives up to the all-inclusive title which it bears. While this is true for the metals it is especially true for the plastics, which are covered in one chapter of nineteen pages.

Copies of this book can be obtained from the Irwin-Farnham Publishing Co., 332 S. Michigan Ave., Chicago 4, Ill., at $4.50 per copy.

I. V. Williams

A Gear and Lubricant Tester—Measures Tooth Strength or Surface Effects

By E. A. Ryder[1]

SYNOPSIS

A simple machine has been constructed for the bench testing of gear materials and gear lubricants at Pratt & Whitney Aircraft. Intended for aircraft engine research, the machine uses as test specimens a pair of gears which are like those used in an actual engine but as simple as possible to manufacture. The various factors affecting the load capacity of gearing are studied separately. The load on the test gears can be changed without stopping the machine. Lubrication of the test gears is controlled separately from oiling of the remainder of the rig. Some remarks on the philosophy of bench testing are included.

The machine described here was developed in 1941 for the investigation of aircraft engine gears. However, it is suitable for the study of other spur gearing by changing the test gears, speeds, etc. Before describing the test rig, the reasons for doing any kind of bench testing are discussed.

THE object of the aircraft gear designer is to design gears to carry a specified load with the smallest and lightest possible parts. The load capacity of gearing depends, among other things, on the geometry, metallurgy, and lubrication of the gear teeth and the nature of the support and loading of the gears.

METHODS OF GEAR RESEARCH

Research on gears, as on anything else, must be broken down into small problems that can be solved. Experimental work must be planned so that only one thing at a time will be changed. The first things to work on are obviously the correction of any current troubles, and after that those factors which offer the best hope of improvement in load capacity or other desiderata.

Just as in testing other components, gears may be studied by testing:

(*a*) the complete engine;
(*b*) the gear set apart from the engine;
(*c*) test gears, which are not actual engine gears; or
(*d*) specimens of material which are not even gears.

Each of these kinds of testing has some uses and some limitations. Test apparatus using rollers or small gears is cheaper and quicker to build and operate than complete gear sets, and if any valid test results can be obtained from the use of such apparatus, it should be used to supplement full-scale tests. Obviously, the relation between bench testing and full-scale testing must be determined to make sure that effort put into the running of rigs is not entirely wasted.

In order to lay out a program of gear research, it is necessary first to consider the various kinds of gear failures and to assess our present position to determine what kinds of phenomena are most in need of study.

THE NATURE OF GEAR FAILURES[2]

(Normal wear or a well run-in appearance is not a failure.)

Failures of Material (dependent on strength, hardness, fatigue resistance): fault of material or design):

Progressive pitting, due to failure of the material in the highly stressed zone just under the surface;

Tooth breakage,
Cracking, chipping, or peening—gear improperly treated; too hard or too soft;

Failure of Lubrication (dependent on surface conditions: fault of lubrication or design, overload or overspeed):

Abrasion and scratching, from dirt;
Scoring and Galling, from different degrees of lubrication failure causing metal to metal contact;
Burning, insufficient oil to cool the tooth surfaces.

THE PLACE FOR BENCH TESTING

Some factors cannot be satisfactorily tested apart from the complete machine. Others, however, can best be tested on some form of bench apparatus because it is more easily possible to hold conditions constant on a small apparatus than on a complete installation. By organizing the testing so that only one thing at a time is changed, it should be possible to determine the effect of separate variables on gear load capacity.

A simple and useful machine for surface-endurance work is the Amsler or Buckingham machine, which consists of two contacting rollers running at unequal surface speeds. This is intended to reproduce the conditions of pressure and slip that occur between gear teeth. Buckingham has done much work on the softer materials, such as bronze and cast iron, but this machine will also deal with hard materials, such as those used in aircraft engines.

Wickenden and his associates have described[3] a machine for evaluating surface durability of gears. This uses two test gears of 7½-deg. helix angle which rotate in different planes at an angle of 15 deg. with each other, thereby developing an elliptical contact area. This pro-

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[1] Consulting Engineer, Pratt & Whitney Aircraft Division, United Aircraft Corp., East Hartford, Conn.

[2] Excellent pictures and descriptions of the several types of gear failures appear in Tentative A.G.M.A. Standard 110.01 for Terms Used in Designating Gear Tooth Wear and Failure, February, 1944. This material was also published in *Machinery*, April, 1946, pp. 166–169.
Several of the pictures are included in this paper through the courtesy of A.G.M.A.

[3] T. H. Wickenden, G. R. Brophy and A. J. Miller, "Evaluating Surface Durability of Gears," *Machine Design*, Vol. 18, No. 7, July, 1946, p. 142.

Courtesy A.G.M.A.[2]

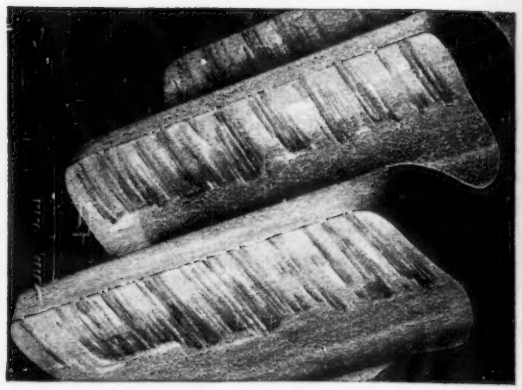
Progressive Pitting

Courtesy A.G.M.A.[2]

Chipping

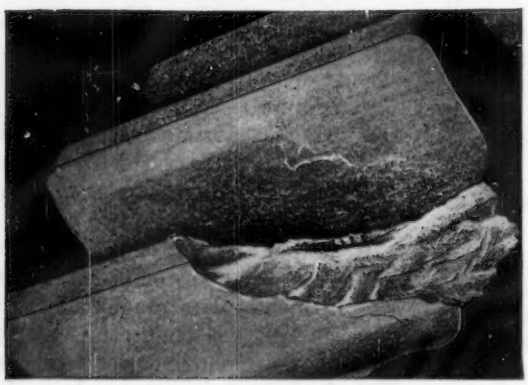
Courtesy A.G.M.A.[2]

Abrasion



Courtesy A.G.M.A.[2]

Scoring

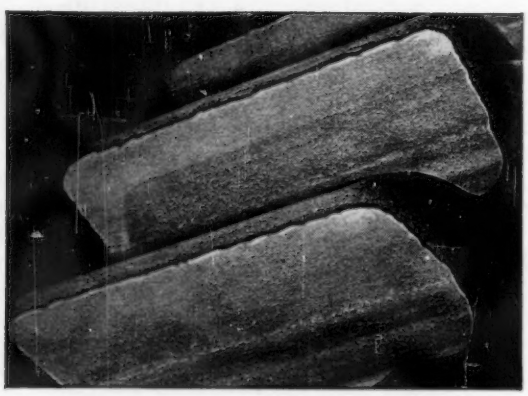


Courtesy A.G.M.A.[2]

Fatigue and Breakage

Courtesy A.G.M.A.[2]

Burning



Courtesy A.G.M.A.[2]

Rolling and Peening

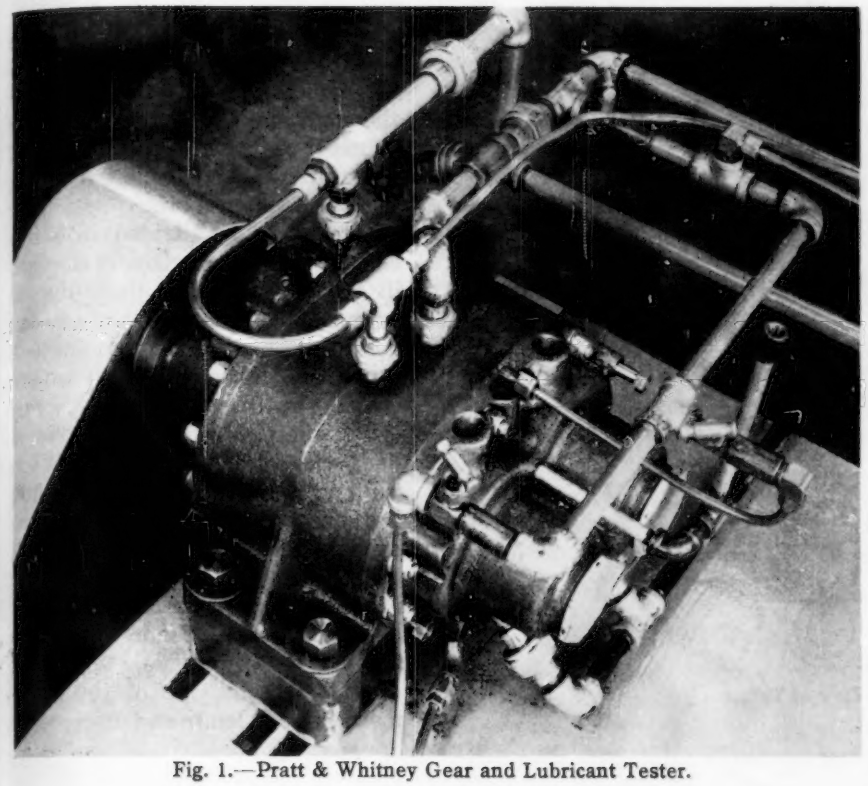


Fig. 1.—Pratt & Whitney Gear and Lubricant Tester.

duces an endwise drag of one tooth upon the other which appears to give conditions somewhat like those existing in hypoid gears. The test gears are quite unlike the spur or bevel gears in prevailing aircraft engines.

The British I.A.E. machine is another four-square rig which, however, uses straight spur gears and is suitable for the study of conditions obtaining in aircraft engines. Until recently, to change load the machine had to be stopped.

The three types of machines mentioned above have been effectively used to study certain factors involved in the operation of high-duty gears, generally either fatigue or scuffing. They constitute evidence that work on test rigs, apart from engines or complete machines, is of definite value and has a place in a development program.

There are many questions regarding both the strength and lubrication of gears that need answering. We should know the effect of oil viscosity on load capacity and the effect of compounded oils as well. The effect of oil flow should be determined and, if possible, cooling and the mere presence of oil should be distinguished. For instance, is a lot of hot oil better than a little cool oil? It is possible to make a long list of items to be studied and, for any one laboratory, it will be necessary to review the field of possible endeavor and select a very few variables which seem most important or which appear to offer the best chance of improvement, and concentrate test work on them.

The Pratt & Whitney Gear-Test Rig

A study of existing bench machines showed the desirability of making an apparatus using actual gears as test specimens and with which one could impose a wide range of reproducible conditions on the test surfaces. This was done. The specimen gears are of aircraft quality, but as simple in design as possible, to reduce manufacturing cost. Figure 1 shows the outside of the machine, which is 12½ in. long.

The familiar four-square or Hopkinson coupling used is shown in the phantom drawing of Fig. 2. Two parallel shafts are connected by two

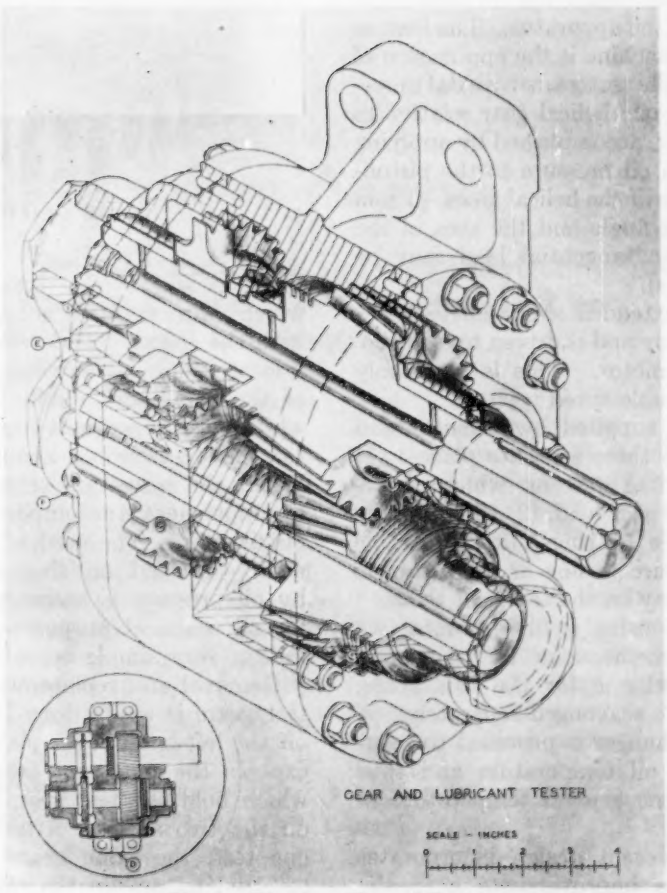


Fig. 2.—Phantom View of Tester.

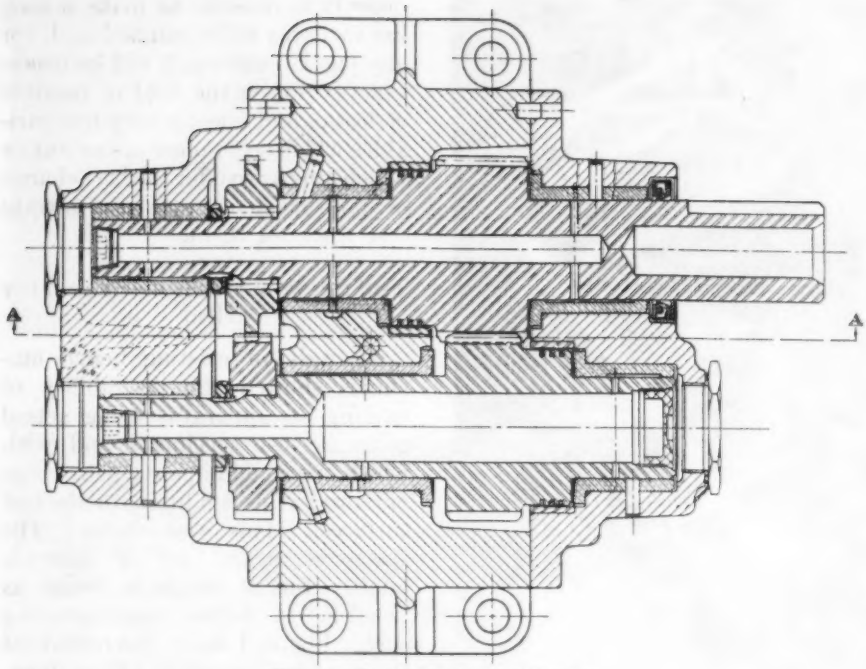


Fig. 3.—Sectional View of Tester.

pairs of gears so that the power required to operate the rig is only the friction horsepower of the gears and bearings. The small spur gears are the replaceable test specimens, while the large helical gears are permanent parts of the apparatus. The feature of this machine is the application of load to the test gears by axial movement of one helical gear relative to the other, accomplished by applying a known oil pressure to the piston-like hubs of the helical gears. From the helix angle and the area of the hubs, the tangential load may be calculated.

The extended shaft carries a V-belt pulley and is driven by a 10-hp. electric motor. This is preferably of a variable speed type.

Oil is supplied by a motor and pump to three separate places: (1) the loading pistons which determine the gear load, (2) 25 psi. to the six sleeve bearings, (3) adjustable oil pressure to one or more squirts which play on the test gear teeth.

The housing is divided into two compartments, one for the main gears and one for the test gears. These are scavenged separately. A heat exchanger is provided to regulate the oil temperature and thus control the general temperature of the rig.

The present design incorporates numerous improvements over the first model. The sectional view, Fig. 3, shows the construction, which employs main gears integral with the shafts. The driving shaft is located endwise between shoulders of the front and middle bushings, while the driven shaft has freedom to move endwise about $\frac{1}{4}$ in. When the gears are turning, this end movement is accomplished without friction. The method of measuring the load on the test gears by oil pressure is accurate enough for all practical purposes and permits a very simple construction.

Removal and replacement of the test gears is easily done by taking off the left-hand cover plate. This exposes the nuts and tab washers which hold the test gears in place on the two shafts. After running one test, the same gears may be reversed to run on the other sides of the teeth. Since the test gears are separated from the main gears by a partition in the housing, it is seldom necessary to disassemble the machine completely, since any debris from the test gears is caught by a filter in the oil line.

As already pointed out, gear failures may be divided into two classes, those due to lack of strength in the material, and those due to surface effects. In either case, one must know when to terminate a test or, in other words, to have a criterion of failure. In the rear cover, there are two plug holes in line with the test gears. When running fatigue tests, surface failure is noted when surface pitting has reached a certain severity. As yet, the attempt to meter this point by mechanical or electrical means has been unsuccessful. The machine is stopped at intervals, depending on the expected life of the specimens, and a lamp and microscope

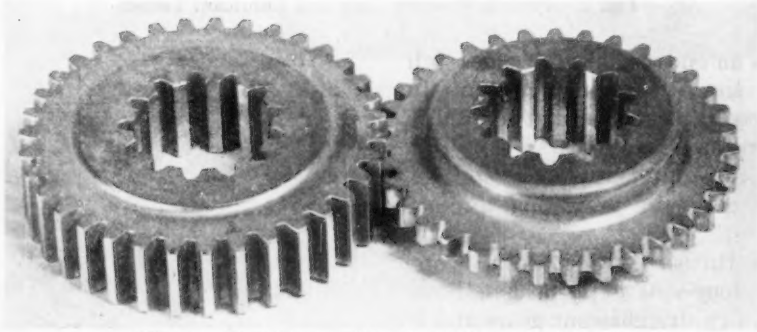


Fig. 4.—Test Gears with Pitch Diameter of 3½ in.

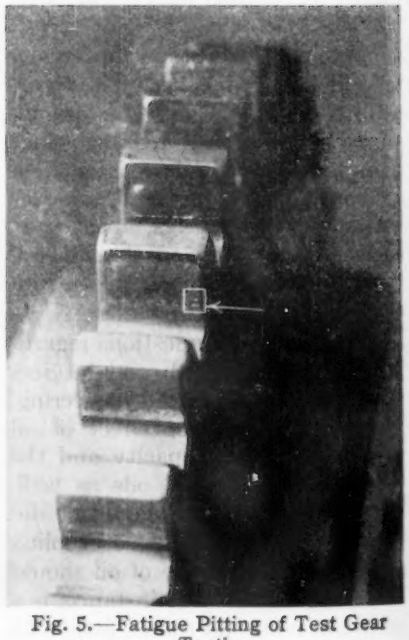


Fig. 5.—Fatigue Pitting of Test Gear Teeth.

are mounted at one inspection hole. The gears are then turned over slowly by hand and the condition of the teeth noted. This is compared with a reference sample previously adopted as a standard.

Tooth fatigue (breaking of the teeth) should correlate with ordinary rotating-beam tests, which are more easily done on the R. R. Moore type of machine. Surface fatigue (pitting) does not so correlate; the knee of the curve of stress *versus* number of cycles occurs at more than 100,000,000 cycles.

Run-in of Specimens

The machine illustrated has been used principally for surface fatigue tests; for each pair of specimens the following run-in procedure is used:

Tooth load, lb. per inch of face	200
Main oil pressure, psi	25
Jet pressure, psi	15
Jet flow, bottom, cu. cm. per sec	10
Jet flow, top	0
Oil in temp., deg. Fahr	160 ±3
Time at 1100 rpm	5 min.
Time at 1650 rpm	10 min.
Time at 2200 rpm	10 min.

The load is then adjusted as required, and the gears are run at 2200 rpm. until failure occurs. A second machine having a more powerful motor and larger bearing clearances is able to run at higher speeds.

Reproducibility of Results

The scatter or deviation of test results is no more than is usual for other kinds of fatigue tests. Three runs on the same material at about the same load resulted as follows:

Test	Rig	Tooth Load, lb. per inch of face	Cycles to Failure
No. 40B	No. 1	3950	15 900 000
No. 59A	No. 1	3900	14 300 000
No. 62A	No. 2	3700	17 000 000

The average deviation in a series of tests is more than shown in this sampling, but is not excessive.

Scuffing Tests

Conditions can be set up to produce scuffing or scoring instead of pitting. The viscosity, temperature, and flow rate of the oil can be varied, and gears may have different hardness or surface finish. Scuffing tests are completed quickly, since it is not necessary to run very long after conditions are stabilized.

The two mating test gears have the same number of teeth, so that examination after run-in will show any gross error in tooth form or finish, and eccentricity or uneven hardness is easily detected. It is felt that for fatigue testing also, hunting teeth would be objectionable.

The Need for Testing

In the aircraft field, there is a lack of data on high-speed gears, for instance, propeller drive gears for gas turbines. The effect of speed on fatigue strength should be evaluated for the hardened materials used in aircraft gears. The effect of speed on scuffing resistance should also be measured. Gear lubrication must be studied further; the effect of oil viscosity has been tested by some investigators, but there seem to be no published data covering the range of speeds and loads of interest to aircraft designers. Treatments to improve the tooth surfaces, or compounding of the lubricant, may permit higher loads to be carried. All these things should be measured by some kind of numbers so that useful comparisons can be made.

Rapid Methods of Grease Analysis[1]

Report by Section I on Chemical and General Laboratory Tests for Lubricating Grease of Technical Committee G on Lubricating Grease, of Committee D-2 on Petroleum Products and Lubricants

Section I on Chemical and General Laboratory Tests for Lubricating Grease, of Technical Committee G on Lubricating Grease undertook a study of methods of grease analysis because of the generally recognized need for improvement in the accuracy and applicability of the present A.S.T.M. Standard Methods of Analysis of Grease (D 128–40).[2] During the course of this study, it became evident that a procedure accurate enough for referee work may be too time-consuming and complex for a rapid control test. Consideration was given to a study of rapid methods particularly adaptable to control purposes, even though it was realized such procedures might not be sufficiently accurate for referee work.

Particular thanks are due to the following members of Section I, who in response to a survey, kindly submitted for consideration five procedures which they had found useful in their work on lubricating greases:

C. J. Boner and G. A. Williams, Battenfeld Grease & Oil Corp.
W. C. Bryant, Swan-Finch Oil Corp.
H. A. McConville, General Electric Co.
N. J. Gothard, Sinclair Refining Co.
W. S. Palmer, The Texas Company

Each method is described briefly in the following paragraphs, although the complete procedures are appended for more detailed reference. A summary of the comments on each method made by members of Section I is included also under the brief description of each method. In this connection it should be pointed out that these comments, except for condensation, are largely unedited; hence the

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[1] Report presented at the January, 1947, meeting of Technical Committee G in Washington, D. C.

[2] 1946 Book of A.S.T.M. Standards, Part III-A, p. 201.

points mentioned may not be regarded by all as being of equal weight.

Determination of Oil in Lubricating Greases (Boner and Williams)

This is a qualitative method of separating mineral oil from lubricating greases, principally for the purpose of obtaining tests on the mineral oil component. Calcium soap greases are heated in the presence of 1 per cent hydrated lime. Sodium soap greases are mixed with approximately five parts of water and boiled. Aluminum soap greases are converted to soda soap by heating with caustic soda and subsequently treating with boiling water.

Although this method provides a rapid means of segregating a quantity of mineral oil, the characteristics of the separated oil may be influenced by the following factors:

(*a*) Adsorptive fillers may preferentially adsorb components of the mineral oil,

(*b*) Calcium soap may not be completely removed,

(*c*) Boiling water hydrolyzes sodium soap, but this may be overcome by the substitution of 50 per cent alcohol, and

(*d*) Some sodium greases give serious emulsification difficulties when boiled with water.

Swan-Finch Control Method (Bryant)

The soap content is determined by calculation after decomposing the grease with crystalline potassium bisulfate, extracting with petroleum ether, and titrating the extract with 0.2 *N* KOH. A method for recovery of the mineral oil involves extraction of the mineral oil from the titrated solutions with petroleum ether and then evaporating the petroleum ether. Fillers may be determined prior to titration by filtration.

Although this procedure is an improvement over Method II of Methods D 128, the use of hydrochloric acid may be preferable for light-colored greases. The results may be subject to some error because it is questionable whether all the neutral fat is removed or whether the soap is completely removed from the ether solution. Some error may be introduced because there is no correction for free fatty acid, and petroleum ether insoluble materials such as asphaltenes are determined as fillers. Difficulties may be experienced with emulsions and also with end points of dark solutions.

General Electric Method for Soap (McConville)

This method involves decomposing the grease by shaking with HCl and petroleum ether, washing the mixture free of mineral acidity and titrating the oil layer with 0.5 *N* alcoholic KOH.

This method appears to be a slight modification of Section 12(*b*) in Methods D 128. The use of heat in decomposing the grease would save time. The method provides no correction for free fatty acids and is difficult to apply to dark oils.

Sinclair Method for Grease (Gothard)

This method is applicable only to sodium soap greases containing no free fat, particularly to railroad types of grease of relatively high soap content. The mineral oil is determined by extracting with 86-deg. naphtha and weighing the residue after the solvent has been evaporated. Free alkali is determined by adding 0.25 *N* HCl and back titrating with caustic solution. The total alkali is determined by the Methods D 128 – 37 for sulfated ash. Combined alkali is obtained by subtracting the free alkali from the total, and the soap is calculated from the combined alkali.

The substitution of 95 per cent alcohol would prevent hydrolysis of the soap. The total alkali will be high if neutral sodium salts are present.

Texas Method for Grease (Palmer)

This method is applicable only to sodium soap greases of the railroad type of relatively high soap content. The sample is ignited in a platinum or porcelain crucible and heated to a dull red heat. The crucible and contents are boiled for 2 hr. in distilled water, and after cooling the water solution is titrated with 0.25 *N* hydrochloric or sulfuric acid using a methyl orange indicator. Soap is calculated from the difference between total alkali as determined above and free alkali.

The method is extremely limited in scope and, like other rapid methods, presupposes knowledge of the composition and manufacture of the grease.

Although written comments were limited in number, the discussion at the June 24, 1946, meeting of Technical Committee G held in Buffalo can be taken as representative of the feeling of the entire membership. The following quotation taken from the minutes of that meeting summarizes this feeling:

"The over-all conclusion was that such methods were inapplicable for referee work since they were definitely predicated on a presupposed knowledge of the composition of the greases. This was emphasized, pointing out that such knowledge of manufacture and composition was, of course, not available to the consumer. Therefore, these short-cut methods could be used only with extreme caution and with a full realization of their limitations."

In other words, the rapid methods could be used by a manufacturer as a matter of routine plant control or could be used for a rapid means of routine inspection by a purchaser, provided there was a full understanding between the seller and the purchaser regarding the applicability of the rapid method and a realization that the A.S.T.M. method or any future revisions should be used for referee purposes whenever a result by the rapid method is questionable.

APPENDIX

Rapid Methods for the Determination of Oil in Lubricating Greases

By C. J. Boner[1] and G. A. Williams[1]

The modern laboratory is confronted with many of the same problems as other departments of industry. One of these is to secure results as promptly as possible. As a result of demands for quick results, methods have been devised for the separation of oils from lubricating greases which consume less time and are more simple than the standard A.S.T.M. method (Sections 15 to 20, (Methods D 128 – 37) A.S.T.M. Standards on Petroleum Products). If care is used in separating oils by these rapid methods, an oil of the same purity and characteristics can be obtained as by use of the standard method. Details of the methods proposed and comparison of oils extracted by the rapid method with the same oils secured by the standard method follow.

The general plan used for the quick separation of oil from calcium greases depends on the fact that most calcium-base greases, if completely dehydrated, will exhibit syneresis. In order to have an abundance of oil separate, it is best to use about 750 g. of greases below 250 penetration and 500 to 600 g. of greases above 250 penetration. The grease is weighed into a 3-qt. kitchen pan, either black iron or granite-ware, and about 1 per cent of hydrated lime added. It is then heated to 300 F. and held there with stirring until thinning is noted, which is usually about 1 min. The sample is then set off the fire to cool. It is then found that at 300 F. the water has left the grease and foaming has ceased. Oils will seldom be encountered in lubricating greases with flash points below 325 F. Hence the oil should not be changed by this treatment. If a very speedy determination is desired on the oil characteristics of the grease, it is preferable to cool in a refrigerator. In any event, when a temperature of about 175 F. is reached, there will result a plastic mass. By working this mass with a spoon or spatula, oil separation will be hastened. Better still, leave the mass until it comes to room temperature when granular soap will separate leaving clear oil which can be poured off. It is preferable to strain the oil through a cloth filter. A close weave of cotton sacking material has been found to make the best filter, giving a speedy filtration yet delivering a clear oil. By the first procedure outlined above —that is, working at about 175 F.—almost twice as much oil is recovered as is true if the mass sets undisturbed until cool. However, the oil in the first case is liable to contain flocks of soap. In case these are evident, reheating to 300 F. and cooling again will cause the soap to coagulate and settle. To assure a final oil free from soap and lime, the oil is centrifuged before any characteristics are determined, using 100-ml. tubes. In most instances, no sediment is obtained on centrifuging.

It may be found that some variation of this general plan will give best results for others. The added lime no doubt has two or three functions and this lime addition can be varied as to amount in most greases. It is believed that the added lime will saponify any free fatty acids and part, if not all, of the free fat which may be in the grease. Further, this deficiency in free fat or fatty acids will cause greater syneresis than otherwise. By using several times as much added lime as is recommended, a cloud in the oil generally results. The same condition has been found when oils alone are heated with hydrated lime to 300 F. and then cooled. The addition of 0.1 to 0.25 per cent of filter cel, both to the grease and to the oil before filtering, has been tried as an additional aid in settling the soap. This seems to offer promise.

As to the limitations and merits of this method, it provides a quick method for the separation of oils from lubricating greases, particularly those containing light-colored and low-viscosity oils. As will be noted from Tables I and II, oils separated by this method check closely in viscosity with those separated by the standard A.S.T.M. method. In most cases, the rapid method recovers an oil somewhat lighter in color than the standard method. The darkening by the latter method may be due to the action of hydrochloric acid or more probably to heating to drive off solvent. Of course, in this more rapid method there is a saving due to no use of solvents but the fire hazard due to their use is removed. Little glass apparatus is used with a consequent saving in breakage. Where fillers such as graphite are present, they are carried down by the mass of soap.

No doubt most laboratories have had customer complaints to the effect that the mineral oil in a grease shipment is not according to specifications. In some such cases, even though the standard A.S.T.M. method was followed, the following errors were found: incomplete soap decomposition by acid with consequent high viscosity report on oil; solvent left in recovered oil resulting in report of low viscosity; oil darker than specifications which was traced to excessive heating to drive off solvent.

This rapid method and the ones following were devised to prevent the above discrepancies, if possible. At the same time, the saving in time is the biggest argument in its favor. It is doubted whether most laboratories can complete a separation of lubricating grease by the standard A.S.T.M. method in less than 5 to 6 hr. With this rapid method they should be able to recover and test the oil in about one fourth this time.

Naturally, this is not a quantitative method for mineral oil in lubricating greases. Further, it is not applicable to rosin greases. It will apply to greases made either from fat acids or from whole fat. No work has been done with greases with added materials such as extreme pressure bases. In the case of calcium greases of high soap content, such as No. 5 Cup, it is sometimes difficult to obtain oil separation by the rapid method. In such instances a small amount of solvent will leach out oil which is afterwards reheated and filtered.

Of course, the same procedure is applicable to smaller quantities of grease where the final viscosity determinations are made by the suspended-level or modified Ostwald viscosimeter.

Those not familiar with this method will no doubt wonder what the effect of small quantities of impurities may be on the recovered mineral oil. Therefore, impurities, such as might be expected, were added to three representative mineral oils and comparative viscosities determined. In each instance, the added material was heated with the oil to 300 F., cooled to room temperature, and centrifuged before viscosity determinations were made. The results are given in Table I.

It is felt that the additions of Table I are much above the possible percentage likely to be encountered in oil recovered by the proposed method. Hence, it is reasonable to conclude that close checks may be expected by this method with the oil actually entering the particular grease. This is borne out by Table II showing representative results obtained by the rapid method and by the standard method on the same grease samples.

[1] Battenfeld Grease and Oil Corp. Kansas City, Mo.

TABLE I.—SAYBOLT VISCOSITIES ON STRAIGHT AND COMPOUNDED MINERAL OILS.

Oil or Compound	Saybolt Universal Viscosities, sec.
300 Vis. at 100 deg. oil	325 at 100 F., 142 at 130 F.
300 Vis. + 2 per cent 42 titer fat	317 at 100 F., 139 at 130 F.
300 Vis. + 2 per cent 38 titer fat acids	310 at 100 F., 138.5 at 130 F.
300 Vis. + 1 per cent lime	327.5 at 100 F., 141.5 at 130 F.
300 Vis. + ¼ per cent NaOH and 1 per cent water	324 at 100 F., 141 at 130 F.
2000 Texas oil	87 at 210 F.
2000 + 2 per cent 42 titer fat	84.5 at 210 F.
2000 + 2 per cent 38 titer fat acids	83.5 at 210 F.
2000 + 1 per cent lime	87 at 210 F.
2000 + ¼ per cent NaOH and 1 per cent water	86.5 at 210 F.
160 bright stock	165 at 210 F.
160 + 1 per cent 42 titer fat	163 at 210 F.
160 + 1 per cent 38 titer fat acids	162 at 210 F.
160 + 1 per cent lime	165.5 at 210 F.
160 + ¼ per cent NaOH and 1 per cent water	164.5 at 210 F.

For the rapid separation of mineral oil from soda-base grease, we depend on the solubility of the soap in water. By carrying out a boiling process in the proper manner it is surprising how rapidly and accurately results can be obtained on the oil component of a grease.

In detail—about 200 to 300 g. of the lubricating grease is placed in a 3- to 4-qt. flat pan together with 1200 to 1500 ml. of boiling water. Boiling is continued until the grease is decomposed and a clear layer of oil appears on the surface. The water is then siphoned off and boiling repeated with fresh water. After 10 to 15 min. this water is removed and fresh added. This procedure is repeated until the wash water on cooling remains clear. Normally four boilings will free an oil of low viscosity from soap, while a heavy oil will require twice this number. It is preferable to make the final separation in a separatory funnel and follow by centrifuging. If the oil is not perfectly clear it should be heated above 212 F. until dry. During the last boiling the addition of 5 ml. of acetic acid will decompose any soap remaining. Further, the addition of a small amount of alcohol to next to the last wash may assist in obtaining a clear oil.

The success of this method depends largely on very intimate contact of the oil with the water. By using a wide pan so that a thin layer of oil is present, this condition prevails. If this method is used it will be found convenient and time-saving to have an abundant supply of boiling water on hand.

As with calcium greases, this method is not quantitative. Also, neither method provides for separation of oils from mixed calcium and soda greases. Of course, the most satisfactory results are obtained with low viscosity oils, but heavy oils do not offer any more trouble than by the standard method and possibly less.

That satisfactory results can be obtained on oils separated by this rapid method is shown in Table III.

TABLE II.—SAYBOLT UNIVERSAL VISCOSITIES OF OILS SEPARATED FROM CALCIUM LUBRICATING GREASES.

Type of Grease	A.S.T.M. Method, sec.	Rapid Method, sec.	Ash, per cent
Air drill	473 at 100 F.	471 at 100 F.	0.01
Cylinder stock chassis	160 at 210 F.	161.5 at 210 F.	
		161 at 210 F. (0.2 per cent filter cel used)	
Chassis lubricant	583 at 100 F.	588 at 100 F.	0.03
		586 at 100 F. (0.02 per cent filter cel)	
F. A. gun	301 at 100 F.	303 at 100 F.	0.01
Graphite Cup	299 at 100 F.	300 at 100 F.	0.004
No. 3 Cup	328 at 100 F.	334 at 100 F.	
Gun	303 at 100 F.	305 at 100 F.	
No. 4 Cup	91 at 100 F.	87.5 at 100 F.	
		87 at 100 F. (no extra lime added)	
No. 4 Cup	140 at 130 F.	137 at 130 F.	0.06
No. 3 Cup	296 at 100 F.	308 at 100 F.	
Dark gun	90 at 210 F.	93 at 210 F.	
Crank pin cup	301 at 100 F.	314 at 100 F.	0.07
Cylinder stock chassis	81 at 210 F.	84 at 210 F.	0.09

consume at least three quarters of an hour. Following this heating, the flask is filled with water when a cake of oil and soap will result in a body of caustic water. The latter can be poured off. If very quick results are desired, boiling with water can be carried out at once. If not, by the following morning considerable clear oil will have separated from the cake in most instances. In any event, the oil must be freed from soap by boiling with water as is done in the case of soda-base greases before it is used for testing.

While this method is successful with strong caustic solution, it is not dependable with weaker solutions. Apparently sodium aluminate is formed and, of course, the fat acids set free are converted to soda soap. While this involves two steps, it is found that the method consumes less time than the regular A.S.T.M. method where characteristics of an oil in an aluminum grease are desired. That the method compares favorably with the standard method is shown by the results in Table IV.

TABLE IV.—SAYBOLT UNIVERSAL VISCOSITIES OF OILS SEPARATED FROM ALUMINUM-BASE GREASES.

Type of Grease	A.S.T.M. Method, sec.	Rapid Method, sec.
Gun	274 at 100 F.	262 at 100 F.
Rocker arm	183 at 210 F.	189 at 210 F.
Chassis	111 at 210 F.	115 at 210 F.
Chassis	128 at 210 F.	131 at 210 F.
Chassis	94 at 210 F.	99 at 210 F.
Gun	298 at 100 F.	299 at 100 F.
Gun	287 at 100 F.	284 at 100 F.

Oil in greases thickened by fillers only, as asbestos tractor lubricants, can be obtained either by heating and filtering or warming and pressing through cloth. Such lubricants, containing less than 10 per cent of filler, if heated to 300 F. will filter through the same type of cloth used for calcium-soap separation. The oil can then be further centrifuged. With higher percentages of filler, warming to 125 F., followed by pressing through cloth, will give enough oil so that it can be further filtered and centrifuged.

This method, of course, does away with solvents and with prolonged heating of the oil which might change its characteristics.

TABLE III.—SAYBOLT UNIVERSAL VISCOSITIES OF OILS SEPARATED FROM SODA-BASE GREASES.

Type of Grease	A.S.T.M. Method, sec.	Rapid Method, sec.	Ash, per cent
No. 2 Sponge	140.5 at 130 F.	140 at 130 F.	
Wheel bearing	369 at 100 F.	370 at 100 F.	
Wheel bearing	75 at 210 F.	82 at 210 F.	0.09
Universal joint	92 at 210 F.	95 at 210 F.	
No. 3 Sponge	340 at 100 F.	347 at 100 F.	0.036
No. 3 Sponge	307 at 100 F.	310 at 100 F.	

For the rapid separation of oil from aluminum-base greases, the aluminum soap is converted to soda soap and then dissolved as is done with regular soda greases. About 200 to 300 g. of aluminum grease is heated with 20 to 25 per cent of its weight of 35 to 40 Baumé caustic soda solution. Heating should be in an Erlenmeyer flask to prevent danger of spattering. It is essential that the caustic solution be mixed very thoroughly with the grease during heating which should

Swan-Finch Control Method (Control Procedure 7-1000)

By W. C. Bryant[1]

Soap Content of Lubricating Greases, Fillers[2] and Viscosity of Mineral Oil

Purpose:

To determine the soap content as the proper base and to extract the mineral oil portion from the same sample for determination of the mineral oil viscosity.

Scope:

Proved satisfactory on soda base, lime base, and mixed soda lime base greases.

Equipment:

One 20-ml. Griffin low form pyrex beaker,
Two 100-ml. Griffin low form pyrex beakers,
One short stem 3-in. funnel,
Two 3-in. analytical funnels,
Three circles of Whatman No. 1 filter paper,
Two 500-ml. pyrex Erlenmeyer flasks,
One funnel support,
One hot plate or sand bath,
Two 500-ml. separatory funnels, and
One 300-ml. pyrex Soxhlet extraction flask, also kinematic viscosimeter and Gooch filtration[1] setups.

Chemicals:

Potassium bisulfate c.p. crystals,
Petroleum ether c.p., pour point 35 to 60 C.,
0.2 *N* aqueous KOH solution,
Neutralized formula 30 alcohol or equivalent ethanol formulation,
1 per cent alcoholic phenolphthalein solution, and
Anhydrous sodium sulfate powder.

Method:

(*a*) In duplicate, weigh 10 g. of the sample to be analyzed, into the 100-ml. beakers. Care is to be exercised in placing sample in beaker so that none adheres to the side of beaker.

To each beaker add 10 g. of medium size crystalline potassium bisulfate.

Place samples on heat unit along with a 100-ml. beaker with 50 ml. of tap water. Adjust heat unit so that tap water is just at boiling point.

With moderate stirring, to give intimate mixture of bisulfate salt and sample, allow the samples to be heated until the soap has been fully broken. This is indicated by the cessation of bubble formation by the sample. The usual reaction time is: 20 min. for soda-base greases; and 40 min. for lime-base greases.

When reaction is complete, the beakers containing the samples are set on watch glasses and allowed to cool to room temperature, or slightly warmer.

(*b*) When the samples are cooled, prepare filter papers and funnels and set up Erlenmeyer flasks to catch the filtered petroleum ether extracts. Extract the samples with as little petroleum ether as possible but extract until the washings of petroleum ether are colorless, or until assured of complete extraction.

(*c*) To the extracts, add 50 ml. of the neutralized alcohol, and 5 drops of the phenolphthalein solution.

Titrate cold with the 0.2 *N* KOH solution until the phenolphthalein end point of the alcohol layer persists for 30 sec. Calculate the proper soap content from the titer factors and titrations.[3]

(*d*) The titrated extracts are combined in one of the separatory funnels and 20 ml. of KOH solution are added, the funnel shaken well. The alcohol layer is allowed to separate. The alcohol layer is drawn into the second separatory funnel which contains 50 ml. of the petroleum ether. The extract in the first funnel is washed with distilled water until the aqueous layer is neutral to phenolphthalein. Each washing is passed through the petroleum ether in the second separatory funnel and discarded. When the extract is washed free of soap, as indicated by neutrality of aqueous layer, the final wash water is drained off as completely as possible. The extract is dried with 10 g. of the anhydrous sodium sulfate powder in the usual manner. The dried extract is drained through the short funnel, fitted with filter circle, and collected in the Soxhlet flask. The petroleum ether is distilled off completely and the flask with the oil residue is placed in a 105 C. oven for 10 min. Ten to 12 ml. of the hot, dried oil is decanted off into the 20-ml. beaker, and allowed to cool.

The cooled air is charged to the kinematic viscosimeter in the usual manner and the viscosity determined in the usual manner at the proper temperature.

(*e*) If fillers such as clay or graphite, etc., are present, filter the extracts from section (*b*) through prepared Gooch filters, and the quantity of fillers can be determined in ordinary manner. The extracts are collected in Erlenmeyer flasks, and the procedure followed as in sections (*c*) and (*d*).

[1] Swan-Finch Oil Corp., Newark, N.J.
[2] See Paragraph (*e*) of this appendix.
[3] One ml. 0.2 *N* KOH = 0.06026 g. calcium oleate, log 2.780029
= 0.06086 g. sodium oleate, log 2.78433

General Electric Co. Soap Determination in Grease

By H. A. McConville[1]

The amount of sample taken depends on the approximate soap content of the grease. If it contains below 10 per cent of soap, take 10 g. of grease, and if it has 25 to 30 per cent soap, take 1 g.

The grease is weighed accurately into a 250-ml. beaker. Dissolve the grease as completely as possible in 75 ml. of petroleum ether, then pour the solution into a 250-ml. Erlenmeyer flask, washing the beaker well with petroleum ether. Rinse the beaker with 50 ml. of 10 per cent HCl and add it to the Erlenmeyer flask. A rubber stopper is inserted and the flask is shaken very thoroughly. The stopper is left in the flask so as to leave the contents under pressure. If the soap content is low, the solution may clear in 10 or 15 min., but with a grease containing 30 per cent soap it may take 1 or 2 hr. Let it stand, with occasional shaking, until the upper layer is perfectly clear and dissolved. Then transfer it to a separatory funnel and draw off the acid solution containing the Na, Ca, or K part of the soap. Wash the petroleum ether fraction at least six times, using 25 ml. of water each time to wash out all traces of acid. Usually by this time the wash water shows neutral when tested with blue litmus paper.

Next the petroleum ether fraction is transferred to an Erlenmeyer flask, the separatory funnel washed with petroleum ether, and washings added to the solution in the flask. At this point 25 ml. of neutral 95 per cent alcohol is added and the solution is titrated cold with 0.5 *N* alcoholic potash using phenolphthalein as an indicator. Duplicate analyses should agree within 0.2 per cent.

Calculation of Soap Content

For example, for a 10-g. sample of grease, 9 ml. of 0.5 *N* alcoholic potash were needed. One cu. cm. of 0.5 *N* KOH = 0.028 g. KOH. Assuming, as A.S.T.M. does, that 1.0 g. of fatty acid requires 0.2 g. of absolute KOH for neutralization, the calculation would be made as follows:

$9 \times 0.028 = 0.252$ g. of KOH used

$\frac{0.252}{0.2} = 1.26$ g. of fatty acid in 10 g. of grease or 12.6 per cent fatty acid

If the soap were Na, to calculate to soap content:

$12.6 \times \frac{305}{282} = 14.2$ per cent Na soap

If the soap were Ca:

$12.6 \times \frac{604}{564} = 13.4$ per cent calcium soap

If a mixture of soaps were present, for very accurate work the ash would have to be analyzed and the soap content distributed in the proportions found there; but for ordinary determinations on ball-

[1] Works Laboratory, General Electric Co., Schenectady, N. Y.

bearing greases a calculation based on Na soap should give results close enough, as it is doubtful whether the error in estimating the soap content would have any effect on predicting the performance of the grease in service.

Analysis of Grease (Sinclair Method)

Routine Method, as Applied to Driving Journal and Rod Cup Greases

By N. J. Gothard[1]

Under no circumstances is any part of the following method to be considered an alternative or substitute procedure for the A.S.T.M. Standard Method of Grease Analysis. The following procedures are intended for those routine control analyses wherein their degree of accuracy has been proved by experience to be sufficient. The following method is applicable only to straight sodium-soap greases containing no free fat, particularly to railroad types of grease of relatively high sodium-soap content.

Petroleum Oil

A sample of 2.5 g. is weighed into a 125-ml. Erlenmeyer flask. About 30 ml. of 86 deg. naphtha is added to the flask, and the sample is broken up with a flat end stirring rod. The solution of oil in the naphtha is then decanted through an 11-cm. quantitative filter paper using slight suction and receiving the filtrate in a 500-ml. suction flask. To avoid possible loss of the naphtha solution, the stem of the filter funnel must extend into the suction flask well past the point of suction. The residue of soap in the Erlenmeyer flask is repeatedly broken up and washed with successive portions of naphtha until the soap is free of oil, whereupon the inside and outside surfaces of the Erlenmeyer flask are washed free of oil. Finally, the filter paper and inner surface of the filter funnel are washed free of oil with successive applications of naphtha. Care must be exercised that no oil is lost by "creeping" and that no flecks of soap pass into the filtrate.

The filter flask is then placed on a steam bath under a current of filtered air until the volume of naphtha solution is about 20 ml. With the aid of a naphtha wash bottle, the residue in the filter flask is completely transferred to a previously dried and weighed 150-ml. beaker. The best technique in this transfer consists in alternate washings of the outer surface near the mouth of the flask and the entire inner surface, avoiding any loss through the side arm of the flask.

After evaporation of the naphtha on a steam bath under an air current and drying for 1 hr. at 105 C. the beaker is cooled and weighed, and the per cent of petroleum oil calculated.

In a few cases, after experience has shown that consistently low results are obtained by using 86 deg. naphtha, due to the highly asphaltic nature of the oil, benzol may be substituted for the naphtha in the above procedure.

[1] Sinclair Refining Co., East Chicago, Ind.

Free Alkali

A 2.5-g. sample is weighed into a 250-ml. Erlenmeyer flask. A second 250-ml. Erlenmeyer flask is used for the blank determination. Into each flask is placed a mixture of 100 ml. of 95 per cent alcohol (Formula No. 30) and 50 ml. of distilled water. There is then added to each flask exactly 10 ml. of 0.25 *N* hydrochloric acid, or an equivalent volume of HCl of other normality. The flasks are then stoppered with perforated corks carrying glass tube air condensers and placed upon a steam bath. The contents of the flasks are refluxed until the sample of grease has completely disintegrated.

The contents of each flask are then titrated with approximately 0.1 *N* NaOH or KOH solution, which has been standardized against benzoic acid. Phenolphthalein is used as indicator and the titrations are continued to a distinctly pink end point. If *A* is the ml. of blank titration, and *B* the ml. of sample titration,

$$\frac{(A - B) \times \text{normality factor} \times 0.4}{\text{Weight of sample}} = \text{per cent free alkali as NaOH}$$

Total Alkali

A sample of 2.5 g. is taken and a determination of sulfated ash is made according to the procedure of Section 6, A.S.T.M. Standard Method D 128 - 37, entitled "Alternative Method for Ash." The following alterations of the published A.S.T.M. Method are made for this procedure:

(*a*) A platinum dish is substituted for a platinum crucible, and in no case is a porcelain crucible to be used.

(*b*) The ash is assumed to be sodium sulfate and is converted to NaOH for the purpose of percentage calculation as follows:

$$\frac{\text{Weight of sulfated ash} \times 0.5632 \times 100}{\text{Weight of sample}} = \text{total alkali as NaOH}$$

Combined Alkali and Soap

Total alkali as NaOH − Free alkali as NaOH = combined alkali as NaOH

Combined alkali as NaOH × 7.625 = sodium soap, if beef tallow is source of soap.

Water

Use A.S.T.M. Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 46).[2]

Calculation

(*a*) *Anhydrous Type.*—Determine free alkali, petroleum oil, and water. Deduct combined results from 100 per cent to obtain soap by difference.

(*b*) *Hydrous Type.*—Determine soap (as in section on Combined Alkali and Soap), petroleum oil, and free alkali. Deduct combined results from 100 per cent to obtain water and glycerin by difference.

[2] 1946 Book of A.S.T.M. Standards, Part III-A, p. 331.

Determination of Sodium Soap in Greases Known to Contain Only Sodium Soap and No Interfering Fillers

By W. S. Palmer[1]

The rapid control method for the determination of sodium soap in greases known to contain only sodium soap and no interfering fillers shall consist of igniting a suitable quantity (2 to 5 g.) of the grease in a platinum or porcelain crucible to a dry carbon. This can best be done by means of a Bunsen burner held in the hand and the sides of the crucible heated until the grease has melted and ignited. Continue to heat the grease gently, supplying only enough heat to make it continue burning, until all the volatile matter has burned away and the dish and contents are at a dull red heat. Remove the crucible and contents at once when this stage has been reached, place in a pyrex beaker filled with distilled water, cover with a watch glass and boil for 2 hr. on a hot plate, disintegrating the carbonaceous residue completely with a stirring rod. At the end of this time determine the total amount of alkali present by titrating the cooled solution with 0.25 *N* hydrochloric or sulfuric acid, using methyl orange as an indicator. From the results of this titration the sodium soap may be calculated by use of a suitable factor found by experience to fit the particular series of products under test. Of course, the amount of free alkali present in the sample will have to be taken into account and corrections made for it. For quick control analyses, this system of analysis obviates the necessity for separating and testing the combined fatty acids.

[1] The Texas Company, Port Arthur, Tex.

Cutting Aircraft Engine Maintenance Cost

By E. A. Droegemueller[1]

THE dependability and regularity of airline service hinges to a large extent on the efficiency with which the aircraft and engines are maintained in flight condition. The maximum usefulness of any aircraft cannot be attained unless the maintenance program is carefully tailored to fit the operation for which the aircraft is intended. Fuel quality has such an effect on engine maintenance that the cheapest fuel may not yield the lowest operating cost. Operators, while striving for the lowest fuel cost, sometimes overlook the more significant matters of reliability and maintenance expenses.

The purpose of this paper is to report unpublished tests of fuel properties that affect maintenance problems. This new information will be of much interest and value to airline operators, since it is pertinent to the question of whether over-all costs might be reduced by an improvement in fuel quality (even at a slightly higher cost per gallon). The conclusions reached here are based both on private correspondence and on unpublished data of tests made at Pratt & Whitney Aircraft.

Heretofore the approach to airline maintenance problems has not been well coordinated among the aircraft operators, the fuel suppliers, and the engine manufacturer. This situation has resulted from the lack of documented knowledge concerning the most efficient ways of maintaining an aircraft engine and its related accessories in top flight condition. The Service Department maintained by Pratt & Whitney Aircraft is gathering such information. A check of each element of engine operation during service is made by field engineers. Detailed reports for each operation are returned to the factory for careful analysis. As a result of this continual analysis and the widespread coverage by the Service engineers, they are able to supply the airlines' maintenance departments with information leading to a minimum of mechanical troubles and delays. The change from relatively small, twin engine aircraft to larger, more expensive four-engine planes on commercial airlines has imposed the need for the most efficient systems of maintenance.

The earning power of the aircraft is diminished in proportion to the time it remains on the ground. The utilization of a plane and the return from the investment in it will be increased by anything which minimizes delays or unscheduled stops or which increases the length of time between periodic checks and between major overhauls. If the measures taken for this purpose cost money, then this cost must be balanced against such advantages as increased flight time and fewer overhauls.

Overhaul Costs:

Figure 1 demonstrates the increased advantage to be gained by lengthening the time between overhauls as the size of the engine increases. The comparative costs are shown for a 20,000-hr. engine life, but also included in Fig. 1 is an insert to show the effect of scrapping the engine sooner. Each overhaul of an engine costs more than the previous overhaul, so that at some time it will be cheaper to buy a new engine than to keep the old one in repair.

Airlines regularly overhaul about 25 per cent of all their engines (including spares) every month. A large airline will overhaul as many as 1000 engines a year. If the use of a better fuel or lubricant resulted in an increase in time between overhauls from 800 to 1200 hr. for such a fleet, the savings in direct overhaul costs would amount to thousands of dollars. More expensive than these regular overhauls, because of the lost flight time and other irregular expenses, are premature removals of engines. Thus, large savings in airline maintenance cost can be obtained if time between engine overhauls can be extended, and premature removals reduced or eliminated. The balance of this paper is devoted to a study of things that now limit engine time between overhauls and are responsible for most premature removals.

Effect of Power Level on Overhaul Costs:

The life of the engine depends on its durability and on the power level at which it is operated.

The periods between overhauls are more or less inversely proportional to the percentage of power

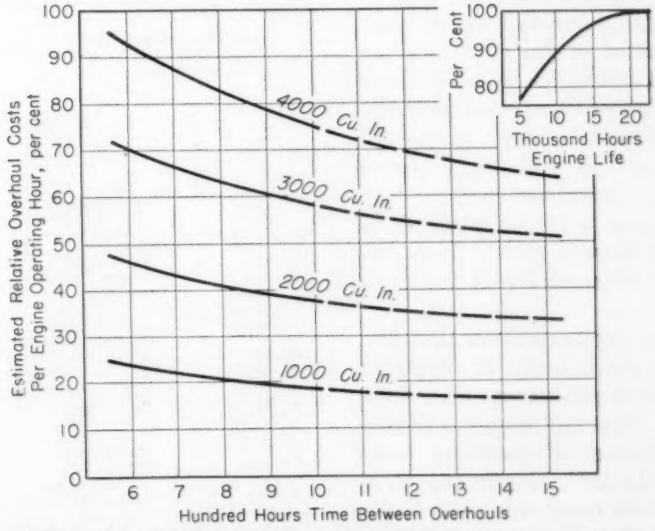


Fig. 1.—Effect of Engine Size and Time Between Overhauls on Overhaul Costs.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Project Engineer, Pratt & Whitney Aircraft, Hartford, Conn.

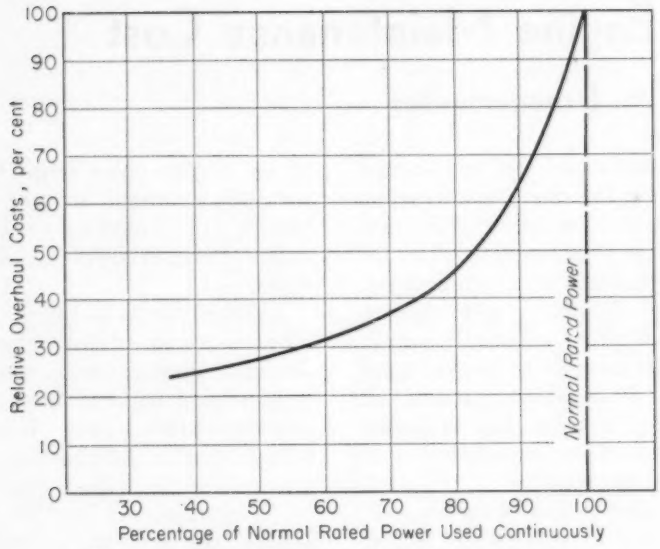


Fig. 2.—Effect of Power Level on Overhaul Costs.

used. Overhaul costs will vary with the power used as indicated by Fig. 2. The values shown are approximate and vary greatly, even at the same percentage of power output, because of other factors such as fuel and lubricant quality.

Effects of Excessive Lead:

While the addition of lead is the only practical way to raise the knock rating of gasoline for continuous cruise operation, no way has been found to scavenge completely the resulting products of combustion from the engine. The general acceptance of leaded gasoline by the motoring public shows that under the usual conditions of operation of motor cars, any undesirable effects from lead are of minor importance. However, the high pressures and temperatures existing in supercharged aircraft engines promote harmful chemical attack on the valves and other parts, and the combustion residues travel throughout the engine by way of the oil and manage to collect in places where they cause trouble.

In this case a lot of medicine is not better than a little. It is important to determine just the right dosage.

We have recommended that the maximum lead limit in aviation fuels be set at pre-war specifications or lower. This will give the engine a better chance of operating more satisfactorily for a greater length of time between overhauls at a lower cost and with greater reliability. It is, in our judgment, the most important item in any fuel specification for airline operation.

History of 100-Octane Fuel Specifications

Despite the increase in cost over 91-octane fuel, our airlines have standardized pretty generally on 100/130 grade fuel. Experience has shown that the better grades of fuel not only give superior performance but reduce the maintenance cost sufficiently to more than make up for the higher fuel bill. Certainly aviation gasoline should not be inferior in any respect to fuel called for in the A.S.T.M. specification of six years ago (D 615–41 T).[2] This calls for a maximum of 3 cu. cm. of tetraethyl lead per gallon and a 50 per cent point of 212 F. maximum for the 100 grade. Table I, giving the history of 100-octane fuel specifications, shows how fuel quality was sacrificed during the war for the sake of quantity production. With artificial restrictions gone, quality can be improved at little or no increase in cost.

[2] Tentative Specifications for Aviation Gasoline, 1941 Supplement to Book of A.S.T.M. Standards, Part III, p. 251.

TABLE II.—CHEMICAL ANALYSIS OF COMBUSTION CHAMBER DEPOSITS.

Element Material	Per Cent
Lead sulfate	35.5
Lead sulfide	28.0
Lead oxide	15.5
Lead bromide	8.0
Carbon	9.0
Organic material	5.0

Fuel Residues Cause Harm in Different Ways

The following sections will show how accumulated deposits in different parts of the engine interfere with proper functioning. Some of these troubles, like pre-ignition, are dangerous, while others merely add to the maintenance trouble and expense.

Location of Deposit	*Effect*
Combustion chamber	Pre-ignition
Spark plugs	Pre-ignition, misfiring
Valves	Corrosion, wear
Induction system	Power loss
Clutch	Stuck clutch
Strainer	Collapsed screen

Combustion-Chamber Deposits:

Figure 3 illustrates the amount of combustion-chamber deposits that can be accumulated during operation. Tests were run both in multi- and single-cylinder engines on fuels containing different quantities of lead, to establish the relation between a reduction in lead content and a reduction in the deposits that might be expected. Figure 4 illustrates this relationship for an R-2800 cylinder. Table II shows a typical

TABLE I.—HISTORY OF "100-OCTANE" FUEL SPECIFICATIONS.

Date	Specification Number	Rating		Tetraethyl Lead	Dye Content, mg. per U. S. gal.	Distillation, deg. Fahr.	
		Lean, octane number	Rich, performance number			90%	50%
6/20/35	2-92	100	None	3	10	275	212
9/7/37	PWA 513[a]	100	None	3	10	*257*	212
2/7/38	2-92A	100	None	3	10	*275*	212
3/1/39	AN-9531	100	None	3	10	275	212
3/20/40	AN-9531-1	100	None	3	10	275	212
9/26/40	AN-VV-F-781	100	None	3	10	275	212
6/41	ASTM-D 615–41 T	100	None	3	10	*257*	212
6/6/41	AN-VV-F-781-3	100	None	3	10	*275*	212
11/14/41	AN-VV-F-781-4	100	None	*4*	*15.3*	275	212
5/13/42	AN-VV-F-781-5	100	*125*	4	*10*	*293*	*221*
12/23/42	AN-F-28	100	*130*	4	*20*	293	221
3/24/43	AN-F-28-1	100	130	4	20	293	221
10/2/43	AN-F-28-2	100	130	*4.6*	*25*	*284*	221
2/23/45	AN-F-28-3	100	130	4.6	23	284	221
7/15/46	PWA-502[a]	100	130	*3*	*14*[b]	*257*	*212*
10/21/46	AN-F-48	100	130	3	14[b]	*275*	*221*
7/1/47	AMS-3032A	100	130	3	14[b]	*257*	221

[a] Pratt & Whitney Aircraft Specifications.
[b] Based on New (Feb. 1, 1947) 1-T Ethyl Fluid Mix.

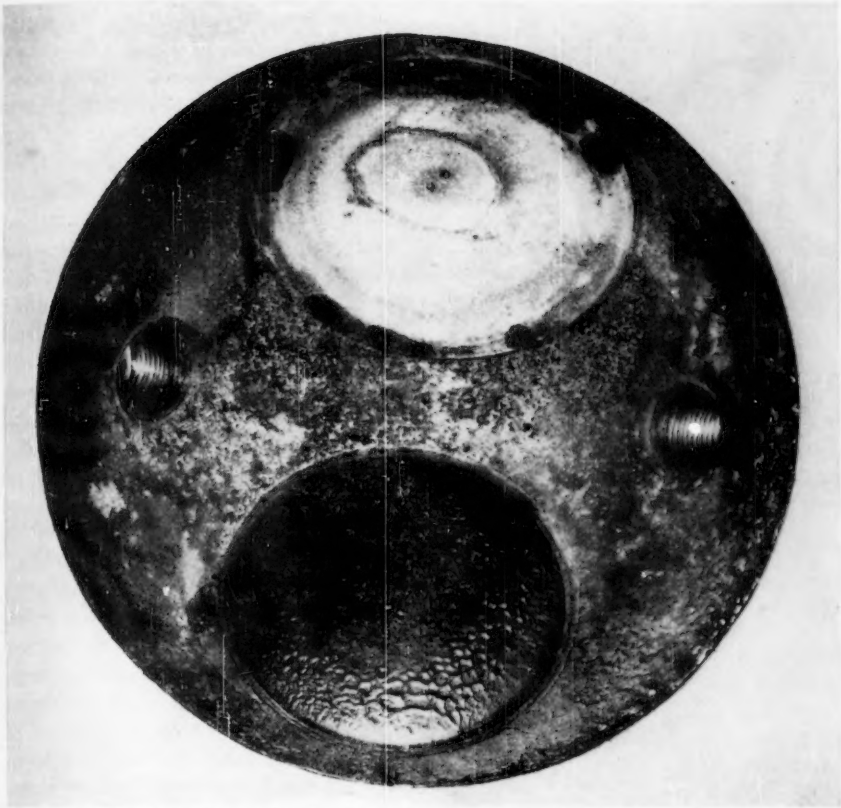


Fig. 3.—Lead Deposits in Combustion Chamber after 365 hr. in an R-4360 Engine.
Fuel with 4.6 cu. cm. tetraethyl lead (l-T fluid) per gallon.

analysis of the deposits scraped from the combustion chamber.

A number of tests were run to determine the effects of engine operating conditions of lead deposits. From these tests a few trends can be observed. Raising the head temperature tends to lower the amount of lead sulfate and sulfide but increases the amount of lead oxide. With lower head temperatures than normal, the reverse is true. Fuel-air ratios richer than best economy tend to increase the percentage of lead bromide in the deposits while leaner fuel-air ratios tend to increase the amount of lead oxide. It is painfully evident that a better lead scavenging agent would be desirable.

Pre-ignition is one of the most disastrous effects of lead deposits in combustion chambers. It is defined as the uncontrolled starting of combustion before the spark occurs at the spark plugs. Pre-ignition difficulties experienced in service and during engine bench tests in recent years have indicated the need for information on its harmful effects and for a possible remedy. During endurance tests several cases of piston burning and destructive backfiring were encountered. Investigation of the cause of the failures showed that pre-ignition was responsible for most of them. Further work (described below) showed that pre-ignition in the engine was traceable to deposits within the combustion chamber. Pre-ignition is unstable; it causes rapid heating of the parts and trouble follows quickly. It is not cured by retarding the spark. It may or may not be accompanied by detonation.

Pre-ignition is fostered by steady operating conditions, and postponed by frequent changes in speed or throttle opening. It can be induced by cruising the engine from 5 to 15 hr. at a steady condition, and is indicated by runaway cylinder temperatures. While sometimes these cylinders clear themselves and the temperatures return to normal without changing the engine power level, during a long cruise operation the engine can be purged to some extent by periodically changing power level or using water injection. This is a way of dodging this kind of trouble, but it might better be attacked at the source, namely, the fuel.

Tests have not yet been finished to determine how long a cylinder can be operated before pre-ignition occurs with each different lead content. However, *tests have been run on an R-2800-CA cylinder using clear fuel for hundreds of hours during which it was impossible to induce pre-ignition with power levels up to the heat-rejection capacity of the cylinder, piston, and valves.* While operating on a fuel with 4 cu. cm. of lead, it was possible to obtain pre-ignition in 15 hr. or less by selecting the operating conditions. The pre-ignition encountered was of an unstable type in which the head temperature would rise 30 to 50 deg. per second, going as high as 650 F. in three or four seconds and returning just as rapidly to normal conditions without changing the engine controls. The temperature recording equipment indicated that these rapid temperature rises occur closer and

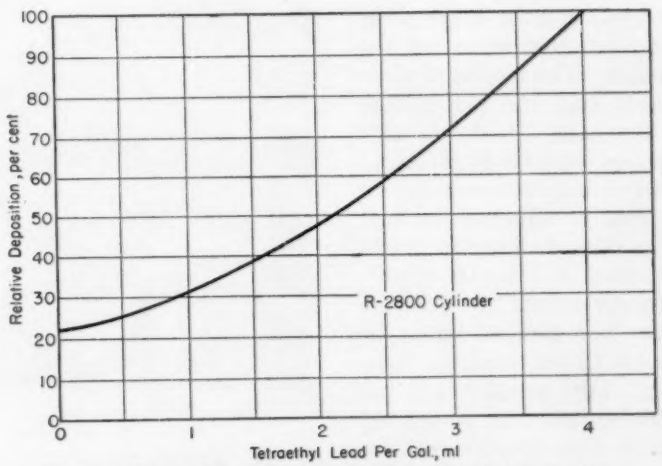


Fig. 4.—Effect of Lead on Combustion Chamber Deposits.

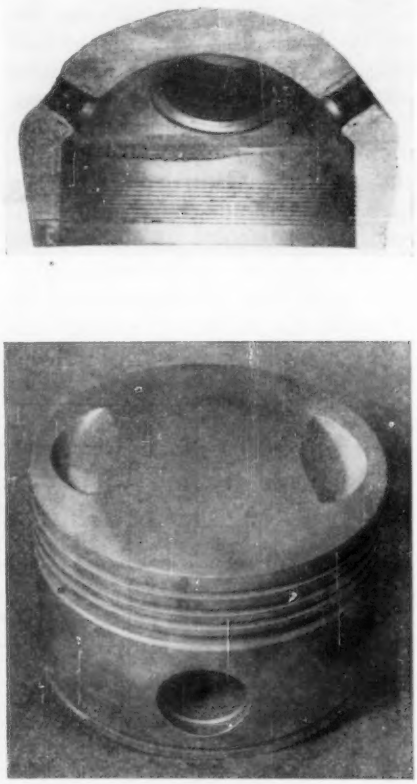
Fig. 5.—R-2800 Piston Damaged by Pre-ignition.

closer together as the total time increases, until the temperature goes overboard and will not return to normal, resulting in a damaged piston as shown by Fig. 5. Peak cylinder pressure measurements made at the time of pre-ignition indicate that the cylinder pressure was from 25 to 40 per cent above normal during pre-ignition.

To be sure about the cause of pre-ignition a number of endurance tests were run in which the engine was operated on a leaded fuel until it had accumulated enough deposits to cause pre-ignition but not to a destructive extent. The cylinder was then removed and the deposits were scraped from the combustion chamber. The cylinder was replaced and again operated, but pre-ignition could not be induced under any conditions. These tests were repeated a number of times, sometimes just replacing the spark plugs and other times just removing the other deposits. The results of these tests indicate that the pre-ignition is due to deposits. While no definite statement can be made as to just how much improvement can be expected from a reduction in lead content, the data do suggest that a small reduction will make a substantial improvement.

Detonation is a kind of knock or ping no more to be tolerated than pre-ignition, but usually not as quickly destructive. It is caused by unsuitable fuel (too low octane number) or too severe engine operating conditions such as excessive boost, or overheating.

Keeping within permissible operating temperatures of the parts exposed to combustion is one of the problems faced by the power plant designer. These temperatures determine the detonating characteristics of a cylinder on a given grade of fuel and thus influence the rating of the engine. This is one reason why engine ratings are always established with the maximum recommended head temperature and carburetor air temperature, and these should not be exceeded under any conditions. It is well known that engines will not disintegrate immediately when operated under detonating conditions, but a number of endurance tests at different detonation levels have been run which demonstrate that the deleterious effect of detonation is cumulative.



Top—R-2800 Cylinder.
Bottom—R-2800 Piston.

Fig. 6.—Erosion Damage Due to Heavy Detonation for 55 hr.

The results of heavy continuous detonation on cylinders and pistons are shown in Fig. 6. The action appears to be mechanical rather than chemical or thermal. To demonstrate this, thermocouples were located where the erosion would occur. It was found that the temperature of the cylinder does not go up radically in the area of a failure, and therefore temperature readings of the cylinder head will not forewarn of this kind of trouble. Any detonation should be considered harmful from a maintenance point of view, and can be avoided by using the proper grade of fuel and keeping within operating limits.

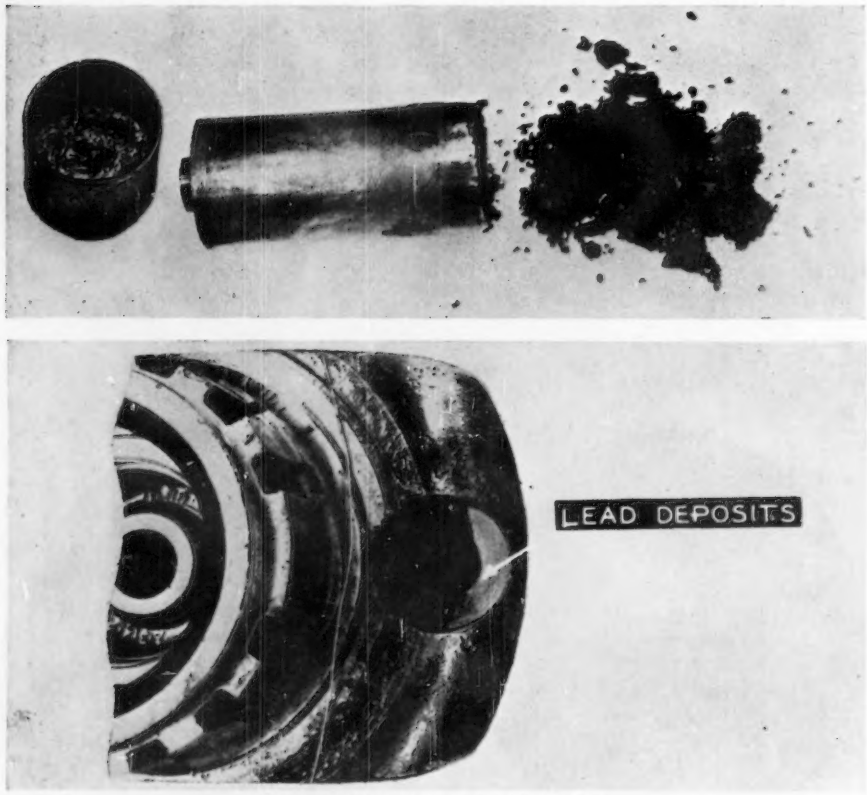
Spark Plugs:

Often a plane keeps its engines idling for a long period after warm-up while awaiting clearance to take off. This allows a high rate of deposit build-up, not only on the spark plug insulators but in the entire combustion chamber. During take-off the deposits melt and flow, causing one or more spark plugs to cut out at this critical moment. The observation that lead is thrown into the spark plugs has been substantiated by actual engine testing. In these tests a replacement of spark plugs often did not remedy the fouling difficulties: new plugs were fouled quickly. This strongly indicates that the material in a free state in the combustion chamber is the cause of fouling, rather than that deposited on the plugs directly from the fuel. However, lead formation along the length of the nose ceramic is often the cause of misfiring.

Spark plugs are generally changed and serviced about every 300 operating hours. A large airline may

Fig. 8.—R-2800 Valves Showing Lead Deposits.
Top—4.6 cu. cm. tetraethyl lead (1-T fluid) per gallon.
Middle—2 cu. cm. tetraethyl lead (1-T fluid) per gallon.
Bottom—Unleaded fuel.

Fig. 7.—Lead Deposits on Spark Plugs.



Top—Reduction Gear Pinion Sludge Cups.
Bottom—Front crankpin bore.

Fig. 9.—Lead Deposits, Representative Samples from R-2000 in Airline Service.

service ten thousand plugs a month, but this is not the only cost involved. The real expense of spark plug trouble is flight delays. Different airlines evaluate flight time differently, but they all value it highly, as any delay is expensive. It has been established that delays due to faulty spark plugs occur on the average of one every 750 operating hours and average 45 to 60 min. each. This would amount to about two delays every day for a large airline.

Figure 7 indicates the seriousness of deposits on spark plugs. The operating conditions for the two engines from which these spark plugs were removed were not the same. The R-4360 engine had been operated at extremely low speed, cold cylinder head temperatures and very lean mixtures; the R-2800 also had cold cylinder temperatures but was operated under higher power. It has been well known for some time that lead deposits on spark plugs cause ignition failures. The point that has not been emphasized is that deposition of lead on spark plugs not only constitutes a flying hazard but also increases the cost of aircraft engine maintenance. It is an obstacle to the development of spark plugs of longer service life.

Valves:

Figure 8 shows the deposits on valves after endurance running with differing amounts of lead in the fuel. Continuous development work proceeds in an attempt to develop a valve guide which can take care of the hard deposits on the lower part of the valve stem. These developments have been successful to a degree. It seems quite clear that if the cause of this deposit on the stem were eliminated it would be unnecessary to combat the problem with mechanical design. If the build-up on the valve stem were stopped, it would be possible further to reduce the valve-to-guide clearance, with a subsequent greater disposal of the valve heat through the reduced clearance and a probable extension of exhaust valve life. These improvements would materially help the operator.

Corrosive attack on valves is a serious problem. At present, exhaust valves have an average life

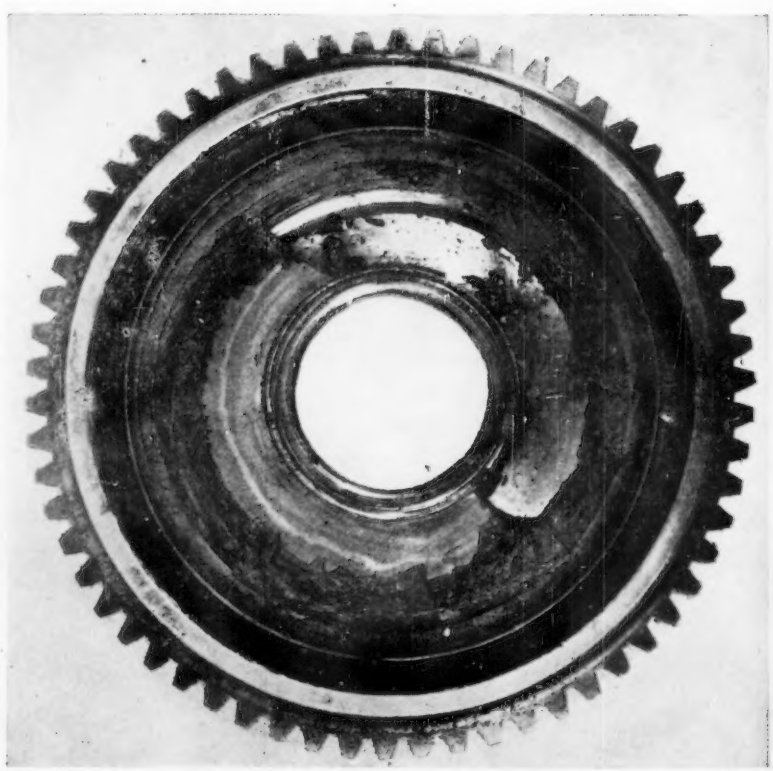


Fig. 10.—Supercharger Clutch from Airline Service Showing Accumulation of Resinous Material.

of about 3700 hr.; intake valves have a life of about 1900 hr. This means that about 20 per cent of the exhaust valves and 50 per cent of the intake valves are replaced at every 1000-hr. overhaul. Tests run on an unleaded fuel indicate that the replacement would be practically zero at the end of 1500 hr. of operation. It cannot be denied that it is possible to make mechanical allowances for the problem, but it must be pointed out again that if such compromises were unnecessary the parts themselves would function much more satisfactorily.

Clutches:

Sludge caused increased trouble when the lead content of fuels was raised at the beginning of the war. It is common to find excessive sludge deposits in crankpins and in the pinion shafts of reduction gears. These are illustrated in Fig. 9. In the early mode of the R-2800 engine there was a long period of development to try to overcome the effects of sludge in the oil feed lines to the supercharger bearings. In this case sludge would fill the passages due to centrifugal action, resulting in the starvation of oil to the impeller thrust plates. This finally was remedied by what was termed the "outside-in oiling fix."

Figure 10 illustrates a sludged clutch. Sludge in any hydraulic coupling always presents a problem. Table III shows an analysis of the deposits removed from a clutch.

TABLE III.—CHEMICAL ANALYSIS OF CLUTCH SLUDGE.

Material	Per Cent
Lead sulfate	2.6
Lead sulfide	30.2
Lead oxide	14.7
Lead bromide	19.7
Carbon	29.8
Organic material	3.0

Oil Screens:

Overhaul manuals recommend cleaning oil screens after every 100 hr. of operating time. However, some airlines are forced to shorten this time to as little as 30 hr. to avoid failures of the parts. This requires a large inventory of screens and the expenditure of a considerable amount of line maintenance time. A collapsed or clogged screen endangers the engine because the unfiltered, bypassed oil may contain damaging material. Figure 11 shows an oil screen which was completely clogged with resinous material after 30 hr. of flight time. A chemical analysis of the deposits on the screen indicates that half the material is the result of breakdown of the lubricating oil, the other half is lead compounds, predominantly lead sulfide, lead bromide, lead oxide, and lead sulfate.

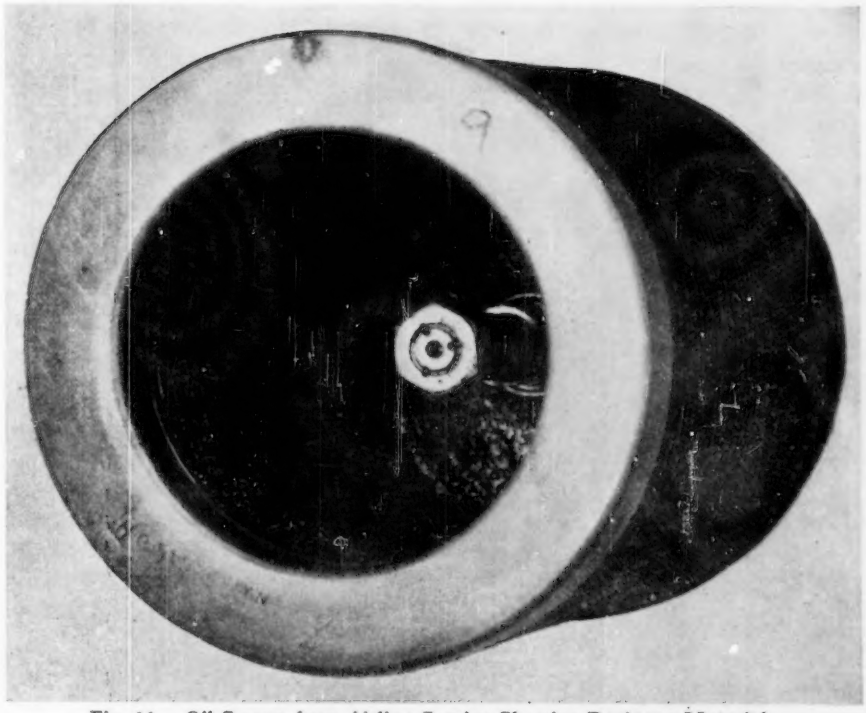


Fig. 11.—Oil Screen from Airline Service Showing Resinous Material.

Many feel that the problem of oil screen clogging is one that can be overcome by the use of an additive type oil. Although it is possible by the use of additives to obtain an oil of almost any desired characteristics, it should be stressed that many additives have certain harmful effects as well as the needed benefits. Although it is possible to obtain a desired property by the use of a particular additive, other important properties of the oil may thereby be destroyed. This requires full evaluation and field tests to determine the over-all significance of any indicated improvement by the use of additives. Another difficulty is that the different additives required to produce the desired properties may not be compatible; and while one additive may produce the desired property with one base oil, it may not necessarily work with another base oil. Therefore, the incorporation of each additive necessitates complete reevaluation for proof of its worth. It is the author's feeling that many of the field complaints that are blamed on the lubricating oil are directly traceable to the fuel, and can only be remedied at the source of the trouble.

Induction System Deposits

The accumulation of hard sludge in blowers, diffusers, and intake pipes cuts down the breathing capacity, and therefore the power of aircraft engines. This problem has been critical with many late model engines. Operators have been forced to pull engines from service before the usual overhaul time because the choking effects of these deposits reduced the engine power. Figure 12 shows the diffuser of an R-1830 engine taken from airline service and an intake pipe of an R-2000 from airline service. Analyses of these deposits and supplementary laboratory tests show that the primary source of trouble is the solid constituents of

TABLE IV.—SOURCE OF INDUCTION SYSTEM DEPOSITS.

Deposit	Per Cent
Dye residue	40
Gum, inhibitor and products of inhibitor oxidation	40
Oxidation products of tetraethyl lead	6
Metal particles, silicate dust, etc.	14

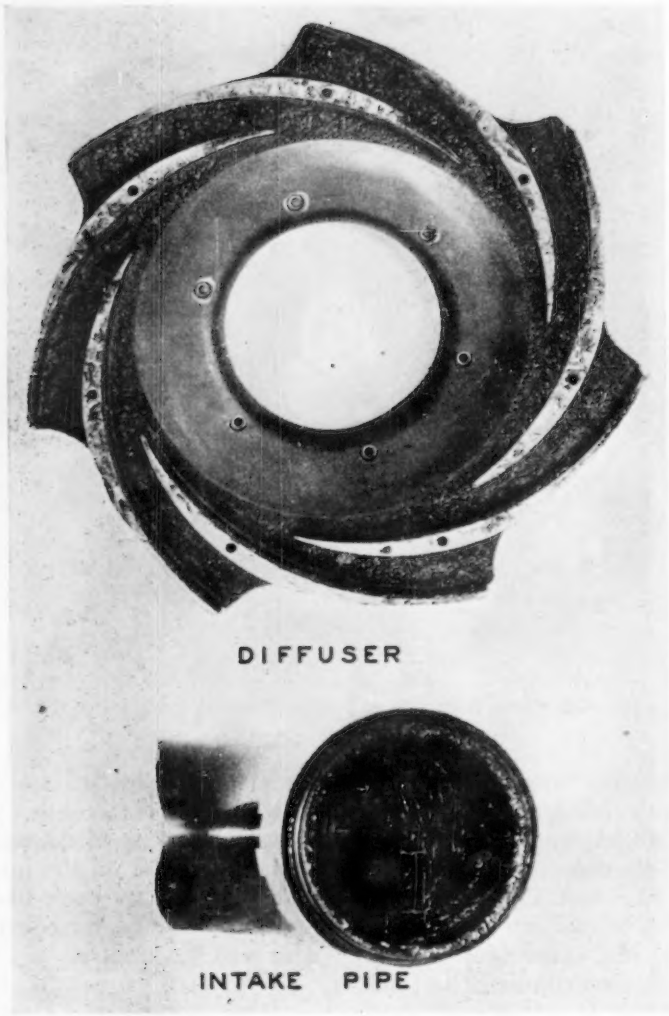


Fig. 12.—Induction System Deposits from Airline Service.

the fuel. Determining the exact source of the deposits is difficult, but the allocation shown in Table IV may be considered to be a fair average. Recently, representatives of the engine manufacturers, the airline operators, petroleum refiners and manufacturers of fuel additives met and concurred in the decision that (1) solid types of inhibitors (aminophenol) would be temporarily eliminated in favor of those of the liquid type (phenylenediamine), (2) the quantity of the inhibitor and dye used in the fuels would be minimized, and (3) fuels with lower lead content are desired. This particular problem of induction system deposits is a typical example of the trouble that fuels can cause maintenance departments. It was pointed out by one airline operator, who was particularly troubled with induction system deposits, that the necessary reduction of load in his airplanes because of the lack of full power from the engines was costing him over $10,000 a day. This cost continued for a number of weeks before adequate changes had been made to stop the trouble. Here is a direct tie-in between the quality of the fuel and the cost of operation and maintenance.

Conclusions

Hidden or indirect costs such as those associated with delayed trips are hard to assess, but we are firmly convinced that (1) a reduction in lead, (2) keeping the operating power level down, (3) using fuels with adequate antiknock rating, and (4) observing operating limits cannot fail to increase engine reliability and should work in the direction of reducing operating costs.

Discussion of Paper on Ignition Temperatures of Rigid Plastics[1]

Messrs. J. W. Westwater[2] and M. G. DeFries[2] (*by letter*).—The detailed description of the test procedure is noteworthy and enables the interested reader to attempt a critical analysis of the scheme. The idea of separting the two phenomena, ignition temperature and rate of burning, is quite sound, and it is hoped that the authors will soon pursue a detailed study of the latter to supplement the paper under discussion.

As was pointed out in the article, the air temperature in the furnace varied considerably from point to point. In fact, Fig. 6 includes one point showing the apparent surface temperature of a sample being hotter than the so-called "furnace temperature." This probably means that the thermocouple used to measure furnace temperatures did not give an indication of what the true furnace temperature was in the immediate vicinity of the sample. From this viewpoint, it would be desirable to locate the furnace thermocouple as close to the sample as conveniently possible.

Since the specimens were rectangular in shape, the edges would be hotter (at least theoretically) than the flat surfaces. If so, ignition would start at an edge and not at the bottom surface near the thermocouple location. A visual observation could confirm or refute this belief. It is obviously desirable to find the surface temperature at the spot of ignition.

A third comment concerns identification of the materials. It is understood that detailed analyses of commercial materials are rarely available, but it would be helpful to know the essential differences be-

[1] E. M. Schoenborn and D. S. Weaver, Jr., "Ignition Temperatures of Rigid Plastics," ASTM Bulletin, No. 146, May, 1947, p. 80.
[2] Research Fellow in Plastics, University of Delaware, Newark, Del.

tween, say, the three types of vinyl chloride acetate used. The ignition temperatures were quite different, but it is not clear whether this is due to a difference in plasticizers or in chloride-acetate ratios.

The fact that apparent ignition temperature varies with furnace temperature poses a problem. Conceivably a furnace temperature must exist for each material which would be just sufficient to cause ignition to occur in an unlimited time. This furnace temperature would be the highest temperature to which the material could be continuously exposed without danger of a fire. Perhaps this temperature, which would undoubtedly be extremely difficult to determine, should be defined as the ignition temperature of the material.

MESSRS. E. M. SCHOENBORN AND D. S. WEAVER, JR. (*authors' closure by letter*).—The authors are grateful to Messrs. Westwater and DeFries for their careful review of this paper.

It is true that the thermocouple used to measure the furnace temperature does not give an indication of the temperature in the immediate vicinity of the sample. This thermocouple was primarily used for purposes of control so that thermal conditions within the heater could be reproduced. It would be of interest to obtain temperature readings very near the surface of the specimen so long as the thermocouple did not interfere with the ignition of the sample. This refinement is worthy of consideration should the method described be revised or extended.

Visual inspection did not indicate that ignition necessarily started at the edges of the sample. The flashing which occurred with some materials was random and ignition was not assumed to have taken place until flame had enveloped the sample.

Since the specimens used in the investigation were commercial materials supplied by various manufacturers, further identification is not made for obvious reasons. The authors agree that the effects of composition, plasticizers, and other addition agents should be determined. It is hoped that this can be done during subsequent phases of the work on flammability.

British Corrosion Committee Reports

Two recent very interesting reports of the British Corrosion Committee have come to our attention. The first of these is a 75-page book published by The Iron and Steel Institute as Special Report No. 31 (price, 5 shillings) and was prepared by Mr. F. Fancutt of the London, Midland and Scottish Railway Co. for the Protective Coating Subcommittee and discusses the effects of different methods of pretreating iron and steel before painting. The report states:

"The dependence of the durability of paint applied to iron and steel upon the surface condition of the metal is strongly emphasized by the results of this investigation. All treatments tested which leave the steel surface in a rust-free, scale-free condition at the time of paint application are comparable in presenting an 'ideal' surface for painting, and the choice between them will generally be determined on economic grounds or convenience of operation.

"The simultaneous presence of rust and scale below a paint film induces rapid breakdown, while light surface rust in the absence of scale, though accelerating paint failure, is not so deleterious, especially where red lead paint is used in priming. Exposure of the descaled steel, unless accompanied by the formation of a visible film of rust, does not, however, shorten the life of paint subsequently applied.

"The durability of paint applied to the as-rolled surface (*i.e.*, scale-bearing, but rust-free), provided that the film of scale is practically complete and unbroken, is much the same as for the scale-free, rust-free surface.

"The rate of breakdown of paint applied to a clean, rust-free, scale-free surface appears to be mainly a function of the paint itself, and to be largely independent of (*a*) the type of steel, (*b*) the descaling method employed, *i.e.*, chemical or mechanical, (*c*) nature of acid used, (*d*) the presence or absence of inhibitors added to the pickling bath, and (*e*) the washing process employed after pickling.

"The life of paint applied to a steel surface not in the ideal condition is, on the other hand, influenced by a number of factors, including (*a*) the type of steel, and (*b*) the nature of acid used, in addition to the sometimes overwhelming factor of surface condition.

"The method of paint application is of importance when it influences the weight of paint applied, and in this investigation spray-applied films were heavier and consequently more durable than brushed ones. Red lead priming is much superior to red oxide on rusty surfaces, but the difference is less, and may even be reversed under certain conditions, when rust-free, scale-free surfaces are involved."

The second is a preprinted copy of Paper No. 21-1946 of the British Corrosion Committee and was written by J. C. Hudson and T. A. Banfield. This report covers the results of five years of exposure tests of the protection of iron and steel by metallic coatings. An account is given of the observations made to date on the behavior of a wide range of protective coatings applied to mild steel exposed to field corrosion tests as part of the investigations of the Protective Coatings Subcommittee. These results cover periods of up to five years in the case of atmospheric exposure and of two years in that of immersion in sea water. The coatings under investigation are aluminum, cadmium, lead, tin, and zinc, together with 82/18 cadmium-zinc alloy and 88/12 lead-tin alloy ("terne"). These were applied in one or more of three standard thicknesses, nominally 1, 3, and 5 mils, by a wide variety of processes, including cementation, electro-deposition, hot-dipping, and spraying. In the last case, specimens were prepared by three types of metal-spraying process, namely, the molten-metal pistol, the powder pistol, and the wire pistol.

The atmospheric exposure test sites used by the committee included three in England—a highly polluted industrial atmosphere at Sheffield; an atmosphere exceptionally free from industrial pollution, but with heavy rainfall, in central Wales (Llanwrtyd Wells); and a south coast marine atmosphere at Calshot. Three overseas test sites were also used—a marine atmosphere near Durban in South Africa; a tropical marine atmosphere near Lagos in Nigeria; and another tropical marine atmosphere in Singapore.

Investigation of the Resistance to Impact Loading of Plastics*

By Halvard Liander,[1] Cyrill Schaub,[1] and Arthur Asplund[1]

Previous Work

In order to assess the application of plastics, as well as certain other insulating materials, it is often necessary to determine the material's resistance to impact loading. It is therefore necessary to obtain some reliable measure of the impact strength which will facilitate not only the selection of the most suitable material but also the calculation and design of various parts to resist all impact stresses which may reasonably be anticipated. Unfortunately, it is not possible to achieve this with the existing methods (1, 2, 3, 4).[2]

For some time it has been known that the result of the impact test, apart from such test conditions as temperature and air humidity (5), is affected by the weight of the pendulum as well as the pendulum velocity at the instant of impact; extensive investigations into these matters have been made by Kuntze, Nitsche and von Mertens (6), among others. In the American specifications the weight and velocity of the pendulum have been specified; this sometimes leads to absurdities. Thus, according to Telfair and Nason (7), a phenolic molding compound with a mica or asbestos filler gives better test results than a wood-flour filled compound, although common experience tells us that the reverse is true. Nitsche and Zebrowski (4) found that the same conditions obtained for compounds with mineral as compared with asbestos fillers and cellulose as compared with wood-flour filler. They have therefore suggested that the impact tests should be made with notched bars as well as unnotched. The relationship between the results obtained in this manner, the "notch factor," will then be a measure of the brittleness and the nearer this value approaches unity the less the brittleness.

For certain materials, however, particularly those with a coarse filler, such as fabric, the notch factor may be greater than unity. This apparent inconsistency is explained by the fact that the fracture is not at right angles to the bar, as was assumed when calculating the resistance to impact, but follows a path producing a considerably larger area. Schob, Nitsche and Salewski (8) therefore query whether the impact work should not be calculated according to bh^2 instead of according to the cross-sectional area bh (b = the width and h = the height of the bar section) but Nitsche (9) has later admitted that the theoretical reasons for basing the calculation on the moment of resistance are not very sound, and he recommends that the normal method of calculating the resistance to impact be continued, that is, on a basis of unit cross-sectional area for the time being. Koon (10) is also of that opinion.

However, the problem has been considered by others and from a different angle of approach. Callendar (11) has carefully analyzed the errors in determining the resistance to impact as obtained with an impact pendulum. It was already known (6) that a considerable loss of energy resulted from the kinetic energy contained in the broken-off portion of the test specimens, particularly in the case of brittle materials. To this error must also be added the work required to break the test specimen once a crack has started, as well as the frictional losses. Telfair and Nason (7) also mention other sources of error, namely, the energy losses in plastic deformation of the test bar and in oscillations in the test machine. These losses, however, are very small in the case of plastics.

Callendar, as well as Telfair and Nason, prefers to follow another method which consists of starting with an energy content in the impact weight which is not sufficient to fracture the test specimen and then gradually increase the impact energy, still using the identical test specimen, until the first crack can be detected. The corresponding energy content, which includes neither the kinetic energy of the fractured pieces nor the energy required to break off the test specimen, is chosen as the measure of the resistance to impact. Extensive tests have indicated that there is no fatigue effect until immediately prior to the final value. Callendar prefers the test specimen to be freely placed on two supports, as in the Charpy test, with the distance between the supports six times the thickness of the specimen. He also found that the pendulum velocity must exceed a certain minimum value, 244 cm. per second, in order to obtain representative results. It is therefore necessary to be able to vary the impact weight within wide limits, and as this is not feasible with an impact pendulum, he prefers the use of a falling-weight machine. Similar suggestions were previously put forward by Church and Daynes (12).

The errors, however, are not confined to the method of determining the resistance to impact. Even the basis for calculating the specific impact energy is erroneous whether based on the cross-sectional area bh or on the expression bh^2.

Impact Flexural Strength and Impact Resistance Value

If the freely supported test specimen is regarded as an elastic beam, the deflection caused by a static load will be

$$\delta = \frac{Pl^3}{48EI}$$

where:

P = the load,
l = the distance between the supports,
E = the modulus of elasticity, and
I = the moment of inertia.

If the rod is assumed to have a rectangular cross-section of width b and height h the equation will be:

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

* Presented at the Fiftieth Annual Meeting, Am. Soc. Testing Mats., Atlantic City, N. J., June 16–20, 1947.

[1] Manager of Materials Lab., and Research Engineers, respectively, Allmänna Svenska Elektriska A. B., Västerås, Sweden.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

$$\delta = \frac{Pl^3}{4Ebh^3}$$

The elastic energy stored in the test specimen will be

$$W_e = \frac{P \cdot \delta}{2} = \frac{P^2 l^3}{8Ebh^3}$$

and the mean energy concentration

$$\bar{a} = \frac{W_e}{lbh} = \frac{P^2 l^2}{8Eb^2h^4}$$

The maximum bending stress for a static load P is

$$\sigma_b = \frac{3Pl}{2bh^2}$$

and the maximum energy concentration

$$a_{max} = \frac{\sigma_b \epsilon}{2} = \frac{\sigma_b^2}{2E} = 9\,\frac{P^2 l^2}{8Eb^2h^4} = 9\bar{a}$$

If the loaded volume of the test bar is denoted V ($V = bhl$) it will be

$$\sigma_b = \sqrt{\frac{18EW_e}{V}}$$

This expression for σ_b, which has already been determined (see, for example, Timoshenko (13)), also holds good nominally for dynamic loading as well. The general formula for the impact flexural strength, that is, the point of rupture, for a specimen of rectangular section subjected to dynamic loading is

$$\sigma_{bi} = \sqrt{\frac{18E_dW}{V}}$$

where E_d is the modulus of elasticity for dynamic loading and W the work required for fracturing the test specimen. This work is the sum of the elastically stored energy W_e and the work that goes into plastic deformation, W_f

$$W = W_e + W_f = P \cdot H$$

if H is the distance through which the weight P falls.

If $E_d = E$, as will be shown in the following, and if the material is elastic, that is, $W_f = 0$, then obviously $\sigma_{bi} = \sigma_b$. For purely elastic materials it is possible to apply data obtained statically to dynamic loading, and it should not be necessary to carry out special impact tests. This has also been pointed out by Marks (14), who has made use of the formula evolved by Timoshenko in a series of tests, mainly on allyl plastics, in a falling-weight machine according to Callendar.

For certain types of plastics, Marks obtained lower test values for the impact strength on dynamic tests than he did with static tests which is theoretically impossible (unless the material is stressed internally). Materials which fractured plastically gave the reverse result, the difference being greater the greater the plasticity of the material.

Practically no plastics are truly elastic, and a more or less plastic deformation occurs at the fracture. In order to give some idea of how such materials react to impact stresses, special impact tests are essential. Having determined the amount of work required to fracture a specimen (excluding all other losses) the result should be expressed partly as the impact flexural strength, σ_{bi}, and partly as the impact resistance value which may be written

$$S = \frac{\sigma_{bi}^2}{E} = \frac{18W}{V}$$

where the constant 18 applies for rectangular sections. Other sections have other constants, for example, 24 for circular sections.

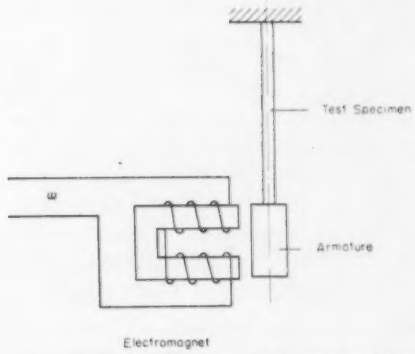
It should be noted that the impact work in the above formula refers to the loaded volume of the test specimen. By this method one obtains experimentally a measure of the characteristic of the material which is independent over a wide range of the method of testing and the dimensions of the specimen.

Dynamic Modulus of Elasticity

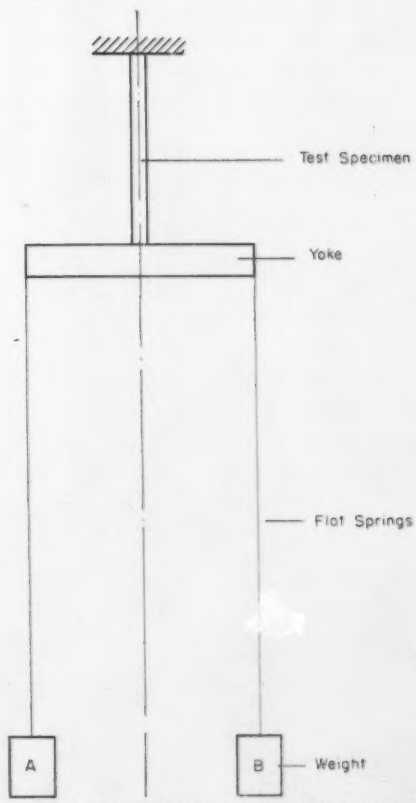
For dynamic bending stresses, the investigations carried out by Frölich (15) show that the dynamic modulus of elasticity is not very different from the static elasticity modulus. Unfortunately, Frölich does not give any comparable data for the materials examined and as these characteristics may vary considerably his investigations are of little value in this connection.

We have therefore determined the static and the dynamic modulus of elasticity for a few plastics. The static determination was obtained by a method which on the whole corresponds with that prescribed in Swiss specifications (16). The dynamic tests were carried out according to a method described by Le Rolland-Sorin (17) and also according to the resonance method.

The Le Rolland-Sorin method is illustrated in Fig. 1. The test specimen is held fast at the top end and the lower end carries a yoke which is connected to two small weights A and B by means of two flat springs. By putting the weight A in motion, the oscillation will be transmitted to B, and a beat will occur at certain intervals. The apparatus was calibrated with steel test specimens of various degrees of rigidity and it became apparent that the calculation formula given by Le Rolland-Sorin did not reproduce the actual



For the determination of the dynamic modulus of elasticity.



For the determination of the modulus of elasticity according to Le Rolland-Sorin.

Fig. 1.—Apparatus for Resonance Method

TABLE I.—MODULUS OF ELASTICITY OF PLASTICS AT ROOM TEMPERATURE.

Material	Modulus of Elasticity, kg. per sq. cm.		
	Static	Le Rolland-Sorin Method	Resonance Method
Wood-flour-filled phenolic molded material..	70 000	84 500	72 000
Mineral-filled phenolic molded material.....	220 000	227 000	215 000
Cellulose-filled urea molded material.....	75 000	.....	70 000
Phenolic paper laminate Asea No. 252.....	100 000	94 500	99 000
Phenolic paper laminate Asea No. 253.....	170 000	186 000	154 000
Methacrylate sheet (Perspex).....	30 000	.....	28 000

conditions. However, the modulus of elasticity could be calculated for the tested materials with the aid of the calibration curve with satisfactory accuracy. The results are given in Table I. Finally, it should be noted in this connection that, owing to the low frequency, the method of determining the modulus according to Le Rolland-Sorin only gives the static modulus of the material for low stresses.

These results were further verified by means of the resonance method which is based on the type of apparatus shown in Fig. 1. The test specimen is rigidly held at the top end, and the low end carries an armature of mass m. The armature is actuated by an electromagnet which is operated on interrupted d. c. of an angular frequency ω. This frequency is varied until the amplitude of the armature oscillation reaches a maximum, $\omega = \omega_{res}$. The dynamic modulus of elasticity of the test specimen may then be written

$$E_d = \frac{m}{g} \cdot \frac{l^3}{3I} \omega_{res}^2$$

where g is the acceleration due to gravity.

The resonance method gives the actual dynamic modulus of elasticity which applies to the test specimen within the actual stress interval, that is to say, for relatively large stresses. The results are collected in Table I which shows that the dynamic modulus for all the materials tested does not differ noticeably from the static modulus.

Experimental Verification of the Formulas for Impact Flexural Strength and the Impact Resistance Value

In order to facilitate comparison of different test methods, a special falling-weight machine has been designed mainly in accordance with the principles put forward by Callendar. The falling-weight machine (Fig. 2) consists essentially of an interchangeable weight guided in rails which is allowed to fall vertically from any suitable height (maximum, 800 mm.) and which strikes a test specimen resting on two supports, the distance between the supports being variable up to 200 mm. The guides in the weight are simple pins with small contact areas so that the frictional losses are negligible for weights exceeding 10 g. The striking edge of the weight has a 3-mm. radius and the weight itself may be made to any arbitrary size.

Preliminary tests are made with the machine in order to obtain some idea of the appropriate weight and height. The actual test is then

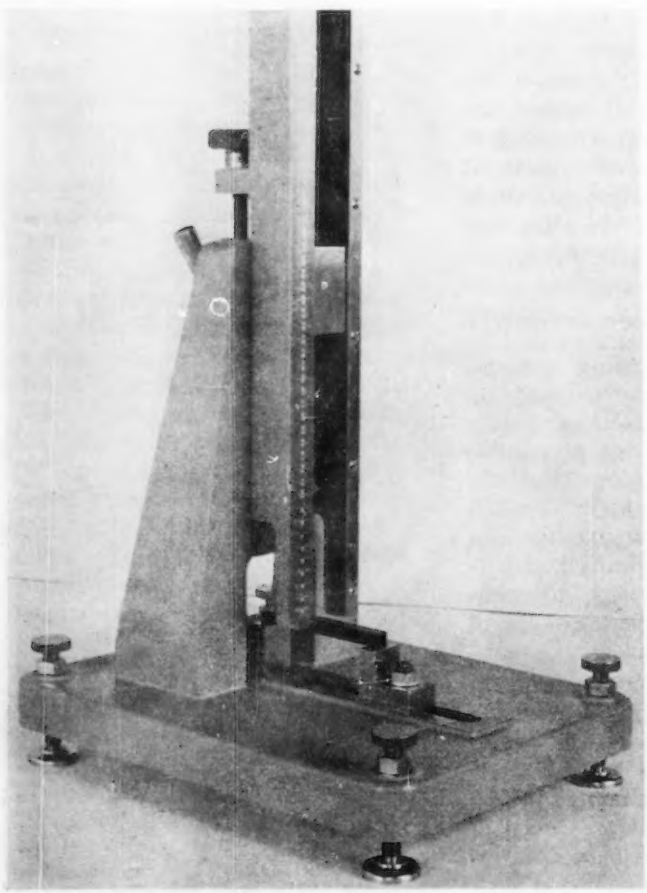


Fig. 2.—Falling Weight Machine.

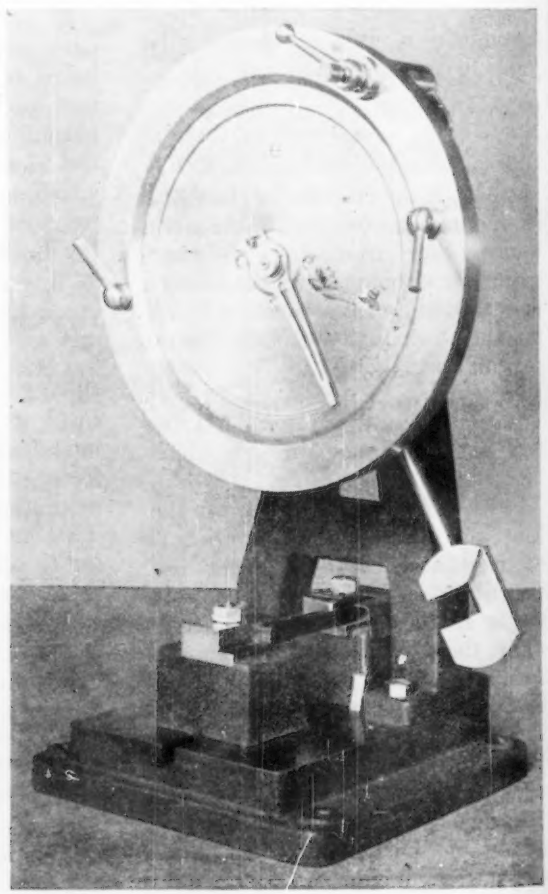


Fig. 3.—Pendulum Machine.

carried out to start with a height corresponding to about 70 per cent of that height which may be expected to fracture the test specimen; the height is then successively increased until fracture occurs. Suitable successive increments would be about 4 to 6 per cent of the test value obtained in the preliminary test. This method usually results in 5 to 6 test blows. As the height at which the fracture just barely occurs, must lie somewhere between the last obtained value prior to fracture and that value which caused the fracture, the final test result is taken as the mean of these two values.

Tests with the impact pendulum (Fig. 3) have been carried out in accordance with the usual single-blow method as well as with the increasing-blow method. The latter method has yielded test results which are in complete agreement with the corresponding results obtained by the falling-weight method. The difference between the value obtained by the single-blow method and the value obtained by the increasing-blow method represents the energy contained in the broken-off portion of the test specimen and other losses. Table II shows examples of the test values obtained for wood-flour-filled phenolic molded material. The tests were carried out on test specimens 120 by 15 by 10 mm. with a distance between supports of 70 mm., and the values given in the table are each the mean of not less than ten tests. In this case the losses which occurred with the single-blow method were found to be 18 per cent of the indicated value. The losses caused by the energy content of the broken-off portion of the test specimens vary with the specific gravity of the material being tested as well as with the dimensions of the test specimen and the energy content of the pendulum.

The test specimens used in these and other tests were made of thermosetting plastics produced in a mold of the dimensions 120 by 15 by 10 mm. Width and thickness were varied within wide limits by the use of inserts in the mold. The wood-flour-filled phenolic was molded at a temperature of 160 C. and a pressure of 250 kg. per sq. cm. for a period of about 1 min. per millimeter of thickness of section. The same figures apply to the mineral-filled phenolic with the exception of the pressure which in this case was 350 kg. per sq. cm. The test specimens were all unnotched and the molded surfaces were left intact on the compression and tension side, whereas the other two sides were ground.

Two qualities of phenolic paper laminates were tested (Asea Nos. 252 and 253) made with different types of resin and different resin contents. The bars were cut out of laminates of different thicknesses in order to obtain unmachined tension and compression sides. Perspex test specimens were also cut out of sheet material.

All the values given are mean values of not less than five tests, usually more. In certain cases series of tests have been made with slightly different materials which is responsible for the minor discrepancies in some of the test results.

According to Callendar (11) the fatigue effect which occurs with repeated impact stresses may be neglected entirely. However, he only tested notched bars and did not investigate the fatigue effect any further than by comparing the results obtained by the single-blow and the increasing-blow methods. It was therefore considered necessary to investigate the matter more thoroughly.

Fatigue curves have been plotted for all the above mentioned materials from test results obtained with test bars 105 mm. long, 15 mm. wide and 3.5 to 10 mm. thick. The distance between the supports was 90 mm. and different weights and heights in the falling-weight machine were employed. Where the number of strokes exceeded 200 without causing fracture, the tests were discontinued. The results are shown graphically in Fig. 4.

The fatigue curve shows the same general characteristics for all the materials tested, and the fatigue limit is usually considerably lower than that impact value which just causes the material to fracture after one blow. The diagram shows, however, that the fatigue effect is easily confined within reasonable limits by choosing a suitable increment of the impact energy. The error will not exceed 5 per cent if the test is carried out as previously described.

It might be expected that the impact velocity should have a certain effect on the result as it is conceivable that the plastic deformation might be related to the time taken to fracture the specimen. Callendar gives, as already mentioned, a minimum velocity for the falling weight of 244 cm. per second. A series of tests carried out on wood-flour-filled phenolic does not fully verify this. Test specimens were used with dimensions 120 by 15 by 10 mm. and a distance between the supports of 90 mm., weights varying from 166 to 1000 g. and heights varying from 11 to 74 cm. As is shown in Fig. 5 velocities between 150 and 400 cm. per second do not have any noticeable effect on the impact-resistance value.

In order to determine the effect of the specimen dimensions, the length, width, and the thickness as well as the distance between supports were varied within wide limits. The results have been plotted in Fig. 6, where the impact flexural strength is shown as a function of the slenderness ratio .

$$\lambda = \frac{l}{h}\sqrt{12}$$

(for rectangular cross-sectional areas).

Figure 6 shows that the impact flexural strength is quite independent of the dimensions, provided that the slenderness ratio exceeds 30, approximately (with a normal test specimen thickness of 10 mm.). This corresponds to a distance between supports of about 90 mm. This holds true for all the materials tested.

TABLE II.—COMPARISON BETWEEN THE VALUES OF IMPACT WORK FOR WOOD-FLOUR-FILLED PHENOLIC MOLDED MATERIAL ACCORDING TO THE SINGLE-BLOW METHOD CARRIED OUT IN AN IMPACT PENDULUM AND THOSE OBTAINED BY THE INCREASING-BLOW METHOD IN AN IMPACT PENDULUM AND A FALLING-WEIGHT MACHINE.

Test Machine		Method	Impact Work
Impact pendulum	25 kg-cm	Single-blow	6.5
	25 kg-cm	Increasing-blow	5.4
	100 kg-cm	Increasing-blow	5.3
Falling-weight	100 g	Increasing-blow	5.3
	250 g	Increasing-blow	5.2
	500 g	Increasing-blow	5.4

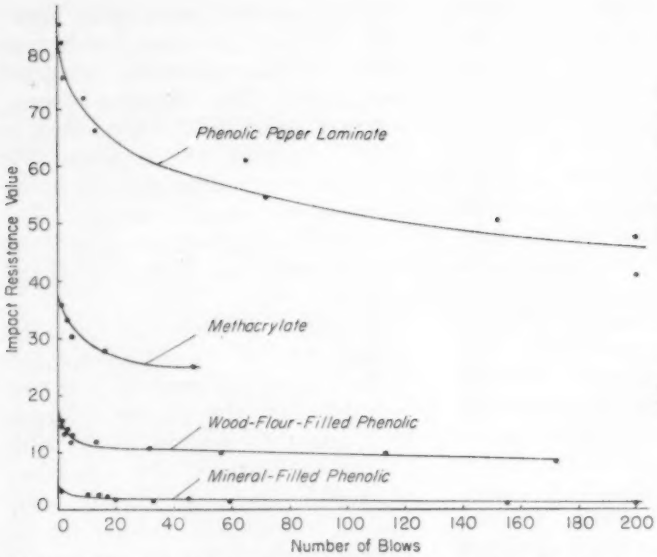


Fig. 4.—The Impact Resistance Value as a Function of the Number of Blows.

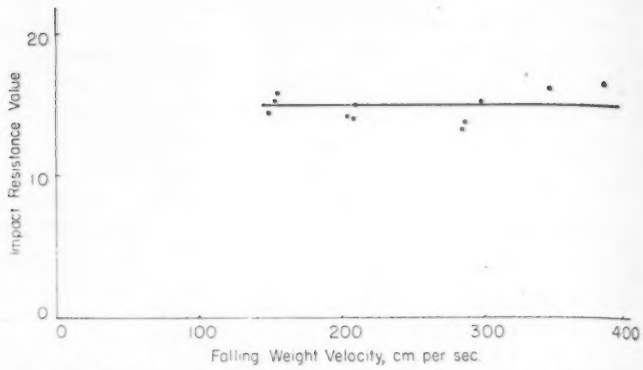


Fig. 5.—The Impact Resistance Value as a Function of the Falling Weight Velocity.

For comparison, the test results on allyl resins given by Marks (14) are shown in Fig. 7. The scatter of the points is more marked owing to the fact that each point represents only one test result, but in spite of this the agreement with our results is quite good.

Correction for Shear and Deformation of the Point of Contact

There is an apparent increase of the impact flexural strength and the impact resistance value when λ is less than 30, and this is because the deformation due to the shear stresses cannot be neglected when testing short specimens. If the specimens are very short, the elastic penetration of the contact points into the test bar also affects the result.

Should it be necessary to determine the impact flexural strength with short specimens it is possible to apply corrections in regard to shear and deformation of the contact point, as is shown by Marks. The complete formula for the beam deflection becomes

$$\delta = \frac{Pl^3}{48EI}\left[1 + 12\mu\frac{E}{G}\cdot\frac{I}{Al^2} + 48\beta'\frac{I}{bl^3}\right]$$

where A is the cross-sectional area, G the modulus of elasticity for shear, μ a factor depending upon the shape of the cross-sectional area, and β' a constant.

For rectangular sections μ is 1.2 and the ratio E/G can be assumed to be $\simeq 3$. The equation then becomes

$$12\mu\frac{E}{G}\cdot\frac{I}{Al^2} = \frac{43}{\lambda^2} \text{ or generally } \frac{\alpha}{\lambda^2}$$

If f denotes the elastic deformation of the point of contact then

$$\beta' = \frac{f\cdot E\cdot b}{P}$$

and if $48\,\beta'\sqrt{12} = \beta$ then

$$48\beta'\frac{I}{bl^3} = \frac{\beta}{\lambda^3}$$

If these expressions are substituted in the equation for the deflection the latter then becomes

$$\delta = \frac{Pl^3}{48EI}\left(1 + \frac{\alpha}{\lambda^2} + \frac{\beta}{\lambda^3}\right)$$

The formula giving the impact flexural strength for short test specimens of rectangular section then becomes, taking into consideration shear stresses and deformation of the point of contact

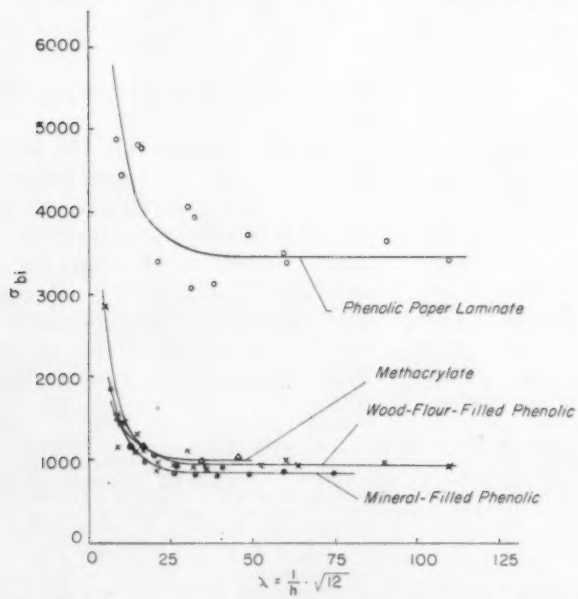


Fig. 6.—The Impact Flexural Strength as a Function of the Slenderness Ratio.

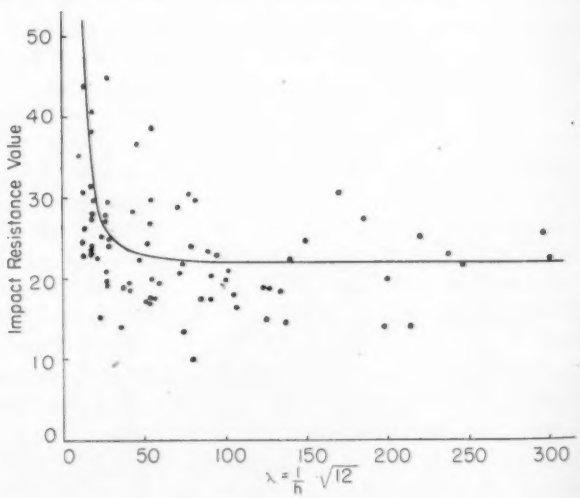


Fig. 7.—The Impact Resistance Value as a Function of the Slenderness Ratio for Allyl Resin According to Measurements by Marks.

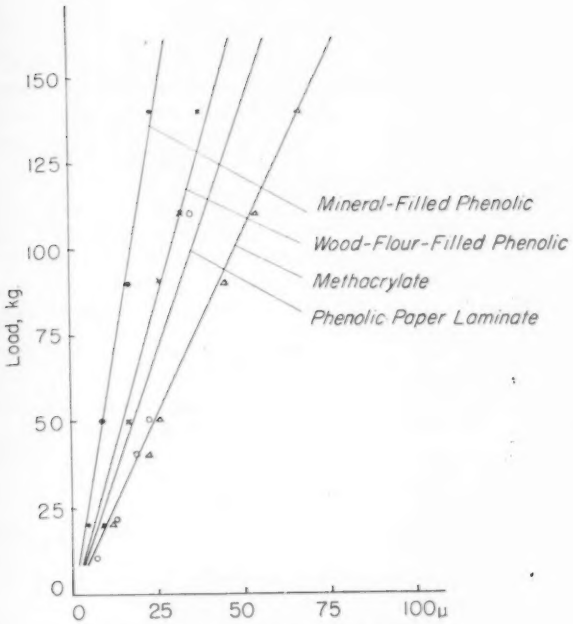


Fig. 8.—Elastic Contact Deformation.

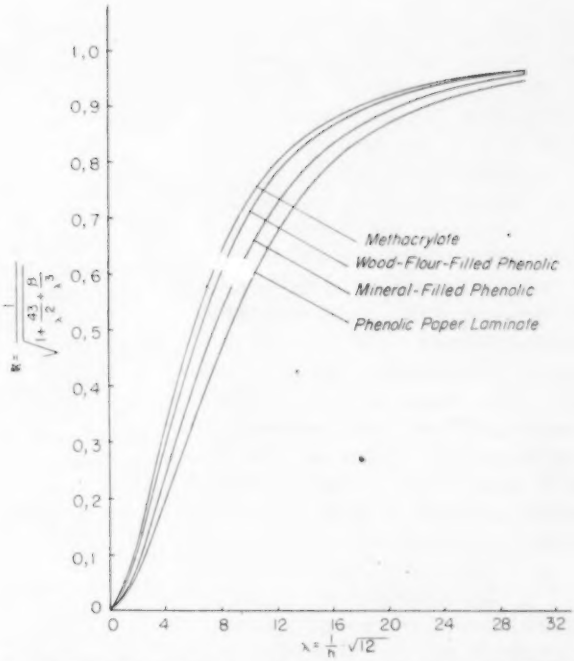


Fig. 9.—Correction Factor for the Impact Strength with Regard to Shear and Contact Deformation at Low Slenderness Ratios.

$$\sigma_{bi} = \sqrt{\frac{cE\bar{a}}{1 + \frac{\alpha}{\lambda^2} + \frac{\beta}{\lambda^3}}} = k\sqrt{cE\bar{a}}$$

The elastic contact deformation for different materials has been determined with a standard hardness testing machine. The results plotted in Fig. 8 were obtained using a contact edge with 3-mm. radius. Each point denotes the mean value of about 20 tests. The curves may be drawn as straight lines without making any noticeable error.

β has been calculated from the curves in Fig. 8 as follows:

Wood-flour-filled phenolic.....	$\beta = 500$
Mineral-filled phenolic.....	900
Phenolic paper laminate, Asea No. 253.....	1500
Methacrylate sheet.....	350

and the constant k may be obtained from the formula

$$k = \frac{1}{\sqrt{1 + \frac{43}{\lambda^2} + \frac{\beta}{\lambda^3}}}$$

The result is given in the diagram, Fig. 9, which shows that the considerable variation of β for various plastics has comparatively small effect on the value of k.

As is shown in the diagram, Fig. 10, the impact flexural strength becomes independent of the dimensions of the test bar, even for quite short bars if corrected with respect to k.

The scatter of the test results for phenolic paper laminate was probably caused by variations in the qualities of the material as these test bars were obtained from laminates of different thicknesses which were not manufactured at the same time.

Conclusion

As has already been mentioned by several authors the commonly used method for determining the impact strength of plastics by means of the impact pendulum, using the single-blow method, gives an incorrect value if no notice is taken of the kinetic energy of the fractured pieces and of other losses. As the result is, in any case, referred to the cross-sectional area of the test specimen

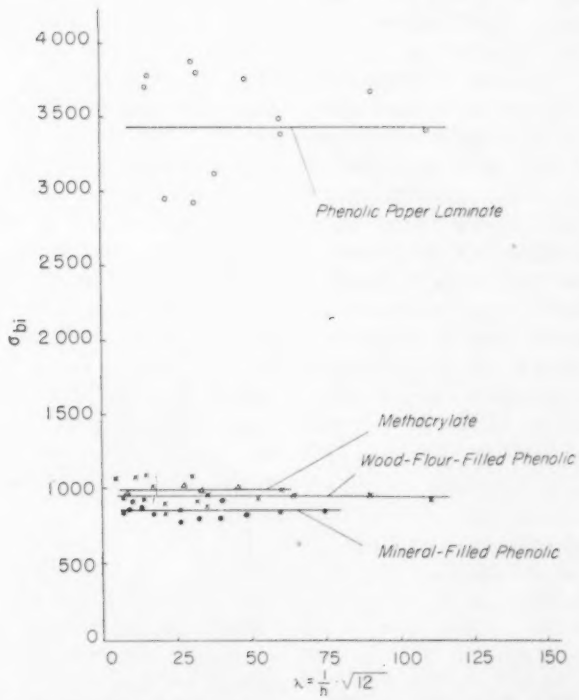


Fig. 10.—The Impact Flexural Strength as a Function of the Slenderness Ratio with Correction for Shear and Contact Deformation.

it only gives comparative values applicable to certain sectional dimensions and fixed conditions of test. By employing the increasing-blow method with a falling-weight machine or a pendulum and by referring to the total loaded volume of the test specimens the impact flexural strength and the impact resistance value obtained thus will give a true measure of the qualities of the material concerned. The test values obtained in this manner have been found to be independent of the dimensions of the test specimen, taking into consideration the effect of shear stresses and deformation of the point of contact in short test specimens.

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Discussion of Paper on A Rapid Method for Accurate Yield Strength Determination Without Stress-Strain Curves[1]

MR. THOMAS J. DOLAN.[2]—The method of yield-point determination proposed by the authors has a definite advantage in that it immediately yields a numerical value without the necessity of additional calculations or plotting of test results. However, it has one inherent disadvantage in that it relies upon absolute accuracy of both load-measuring and strain-measuring instruments; sufficient data are not accumulated to detect erratic errors in the readings of strain or of load that may occur due to defects in the test setup.

Many commonly used types of strain-measuring devices utilize mechanical levers and dial indicators for multiplication and indication of the strains. These mechanical instruments invariably have a backlash or slack which will vary each time the instrument is applied to a new test specimen. It is thus not possible to set the zero strain reading precisely corresponding to zero load. The proposed method requires that the total strain be measured from a true zero position and assumes a corresponding elastic slope equal to the modulus of elasticity of the material. Thus, erratic errors, in addition to those possible errors mentioned by the authors, would creep in from one specimen to the next, which in some cases (depending on the accuracy of the strain-measuring instrument) might reach considerable proportions.

For materials whose stress-strain relation does not deviate markedly from a straight line with an abrupt "knee," or for cases in which yield strengths corresponding to small offsets are desired, this erratic error due to backlash in the strain-measuring instrument would lead to an appreciable error in the determination of yield strength.

Undoubtedly the proposed method would require more manual skill and dexterity or training and experience to obtain accurate results than the simple autographic recording of test data and interpretation of curves. The operator must combine mechanical operation of the machine with mental calculation of the end point to be reached during the test. For some individuals, this would require considerable training to be able to perform satisfactorily and repeat readings to any degree of precision.

Another drawback to the method is that it relies upon absolute infallibility of the operator to arrive at the correct end point of the test. No actual data are available after completion of the test to check either the performance of the operator or the operation of machine and test equipment. When stress-strain data are recorded and plotted,

[1] L. J. Ebert, M. L. Fried, and A. R. Toole, "A Rapid Method for Accurate Yield Strength Determination Without Stress-Strain Curves," ASTM BULLETIN, No. 145, March, 1947, p. 50.

[2] Research Professor of Theoretical and Applied Mechanics, University of Illinois, Urbana, Ill.

small deviations caused by erratic behavior of load- or strain-indicating apparatus can readily be detected and often can be corrected by proper interpretation of the data.

These comments should not be taken as a condemnation of the procedure suggested by the authors, but rather as supplementary precautions to be observed when using the method in other laboratories with different equipment, materials, and personnel. As the authors have shown, the method is undoubtedly a rapid means of routine testing where a large number of specimens must be handled, and it is particularly suited to those metals that show a rather abrupt "knee" in the stress-strain relationship.

MR. L. J. EBERT (*authors' closure*).—The authors are indebted to Mr. Dolan for his interest and criticisms, and agree that certain additional precautions might well be pointed out in the use of the Method for Determining Strength outlined in our paper. Mr. Dolan points out several pitfalls which might be encountered in this testing method, or in any other fast method. However, each of the sources of error can be avoided with the exercise of appropriate precautions.

Regarding the errors in the strain-measuring instruments caused by backlash or slack, it should be mentioned that these errors can be avoided by a careful adjustment of the extensometer. Moreover, they can be detected in testing before the test has progressed to the point where plastic straining begins, by means of calculating before the test the strain at an arbitrarily selected load low in the elastic region for the given test bar diameter. This calculation may be made simply by subtracting the 0.2 per cent strain value (40 units on the gage reading scale of the slide shown in Fig. 1 of the paper) from the total elongation value. (Charts are available which give the total elongation values for very low loads.) Then as the test proceeds, if the extensometer reading is not what it should be for this low elastic load, it may be assumed that the extensometer is in error and the test may be stopped without damage to the test specimen. Proper remedial measures can then be taken.

In actual practice, this method of checking the extensometer has been found to be quite satisfactory. The added effort involved has been shown to be small, since most of the bars tested have such a small variation in diameter that a single calculation of the type described above is sufficient for any given material.

Errors introduced because of the load weighing mechanism not functioning properly, of course, cannot be detected. However, it is also true that if the testing machine is out of calibration, as would be indicated in this case, the error introduced cannot be determined by any testing method.

The testing of materials with a high strain-hardening rate in the region of 0.2 per cent plastic strain has been performed quite satisfactorily by use of the Rapid Method. As a matter of fact, this procedure for yield strength determination was developed primarily for the testing of cast aluminum alloys which are characterized by the absence of this "knee" in the stress-strain curve referred to by Mr. Dolan.

The authors agree that the proper use of this testing method requires a certain degree of alertness in the operator. It is necessary for him to watch two pairs of values as the test proceeds, until these two pairs become nearly identical. However, it has been found that difficulty encountered from this source is relatively small, and is reflected only by a slower rate of testing for inexperienced operators. The average operator would probably require about forty tests to attain a reasonable testing rate.

Lack of a permanent record of the stress-strain curve for back-checking purposes, which Mr. Dolan notes, is not a serious drawback. It can be pointed out that in testing bars with autographic stress-strain recorders (or by manual recording and plotting of data) no permanent record is made of tensile strength, an equally important value in tension testing, since in most cases the elimination of damage to the extensometer necessitates removing it from the specimen long before fracture. This is particularly true for materials which fracture at maximum load.

The authors also wish to point out in conclusion that the Rapid Method was not developed to compete with any test method of high accuracy. It is intended to provide a fast and inexpensive means of determining yield strength with average accuracy, and with the use of relatively rugged equipment.

MR. W. A. D. DAWSON.[3]—Our attention has been drawn to the article by L. J. Ebert, M. L. Fried, and A. R. Toole, in the ASTM BULLETIN for March, 1947, from which it would appear that the authors are unaware of the results achieved by such British workers as Skerry, Lindley, Crow, and Beaumont in this field. For mass testing materials whose properties can be predicted with some accuracy the new method is inferior to the four-point system used in this country for about fifteen years, both as regards speed and accuracy. For materials with a wider range, the method recently devised by Mr. R. A. Beaumont is considered to be superior to any previous scheme.

That these two methods are of proved accuracy is attested by the fact that both are permitted by the British Ministry of Aircraft Production for use on aeronautical materials.

Against the method advocated by Messrs. Ebert, Fried, and Toole, two very serious objections may be raised:

(*a*) It is a well-known fact that extensometer readings at very low stresses are likely to be erratic and the scheme makes no provison for excluding or revealing these erroneous values.

(*b*) By the omission by any check based on the known modulus of elasticity of the material, error due to faulty calculations, bent or badly aligned specimens may remain undetected.

The Lindley extensometer was designed with high sensitivity and high accuracy as these are essential in any instrument used in accordance with the four-point Beaumont schemes.

MR. EBERT (*authors' closure*).—The authors are grateful to Mr. Dawson for his interest in the paper as evidenced by the critical analysis which he made.

[3] Director, J. E. Baty & Co., Ltd., London, England.

To answer Mr. Dawson's specific objections, the authors wish to point out that it is possible to check a given test in the low-stress region merely by calculating the elongation at one or two pre-selected loads in the elastic region. These check points may be used universally for all test bars of a given material, provided that the diameters are approximately the same. Calculations may be dispensed with if use is made of the charts referred to in the paper, because the elastic strain for any given load (on the charts) may be found by subtracting 40 units from the corresponding total strain. By comparing the result with the actual reading on the extensometer, the operation of the equipment and the behavior of the specimen can be checked up to the elastic limit. By this method, the occasional errors caused by erratic extensometer readings and faulty alignment of specimens may be detected and corrected.

The test method proposed in the paper is formulated on the basis of the known modulus of elasticity and most of the necessary calculations were made in establishing the test method. The actual use of the test method involves only the presence of an alert operator; the possibility for errors resulting from faulty calculations in testing are practically eliminated, since the only calculation remaining for the operator is merely one of dividing the yield load by the cross-section of the test bar.

Regarding actual variations in elastic modulus for a given material, it has been the experience of the authors after performing thousands of tension tests on cast aluminum alloys that variation among specimens is so small that the yield strength is only negligibly affected.

The authors question the use of an extensometer of higher sensitivity than that referred to in the paper, except for modulus determination, special stress-strain curves, etc. The Rapid Method used with the aid of an ordinary extensometer is at least as accurate as the measurements of specimen size and applied load. Consequently, a more accurate extensometer is not necessary.

A Variable-Span Flexure Test Jig for Plastic Specimens

By B. M. Axilrod,[1] R. W. Thiebeau,[2] and G. E. Brenner[2]

SYNOPSIS

A flexure test apparatus is described for testing a plastic specimen as a simple beam loaded at the center. The equipment is designed so that the span may be quickly adjusted to the desired value with a calibrated screw. This facilitates testing specimens of different thicknesses at the same span-depth ratio.

The application of a deflection lever with a recording extensometer for obtaining load-deflection graphs with the flexure apparatus is also discussed.

IN THE flexure testing of plastics, both for specification and other purposes, the specimen is usually tested as a simple beam loaded at mid-span. The spans encountered are usually between 0.5 and 8 in. Early work at the National Bureau of Standards in flexure testing of plastics was carried out with a flexure jig whose span was adjustable as required in Federal Specifications L-P-406 and L-P-406a.[3] The support pieces were arranged to slide in a shallow channel in the base of the flexure jig; when the desired span was obtained the supports were locked in place. This apparatus had several disadvantages.

It was found that measuring the span to 0.01 in., as required in the above specifications, could not be done quickly; likewise, adjusting the span to within 0.01 in. of the desired value was a trial-and-error affair. Furthermore when the span was changed, the realignment, that is, centering the pressure piece and making it parallel to the supports, was slow.

Frequently the test specimens taken from molded articles or experimental laminates were too short to be tested at a span-depth ratio of 16:1 or more as prescribed by the revised Federal Specification[3] and also by the A.S.T.M. Tentative Method of Flexural Test of Plastics, D 790 – 45 T.[4] Since it was known that the flexural strength increased as the span-depth ratio decreased (1)[5] particularly for ratios under about 10:1, it was necessary that the span-depth ratio be kept constant in any comparative series of tests. Therefore, the apparatus described herein was developed to facilitate adjustment of the span in flexure testing.

DESCRIPTION OF APPARATUS

Flexure Jig:

The principle of operation of the flexure jig is very simple: Support blocks which slide in the base of the jig are moved by a screw having right- and left-hand threads, respectively, on the right- and left-hand portions of the screw, similar to a roller-skate clamp.

The apparatus was designed with two sets of support blocks, one with $\frac{1}{8}$-in. radius contact edges required by the specifications[3, 4] for testing plastics, the other with $\frac{1}{32}$-in. radius support blocks for material $\frac{1}{16}$ to $\frac{1}{8}$ in. in thickness. The range of spans is 0.5 to 2.1 in. for the $\frac{1}{32}$-in. radius, and 1.6 to 9 in. for the $\frac{1}{8}$-in. radius supports.

Assembly drawings of the flexure jig with the two sets of support

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

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[2] Instrument Maker, Instrument Shop, National Bureau of Standards, Washington, D. C.

[3] Federal Specification L-P-406a (Superseding Federal Specification L-P-406, December 9, 1942): Plastics, Organic; General Specifications Test Methods; January 24, 1944; Government Printing Office, Washington 25, D. C.

[4] 1946 Book of A.S.T.M. Standards, Part III-B, p. 858.

[5] The boldface numbers in parentheses refer to the references appended to this paper.

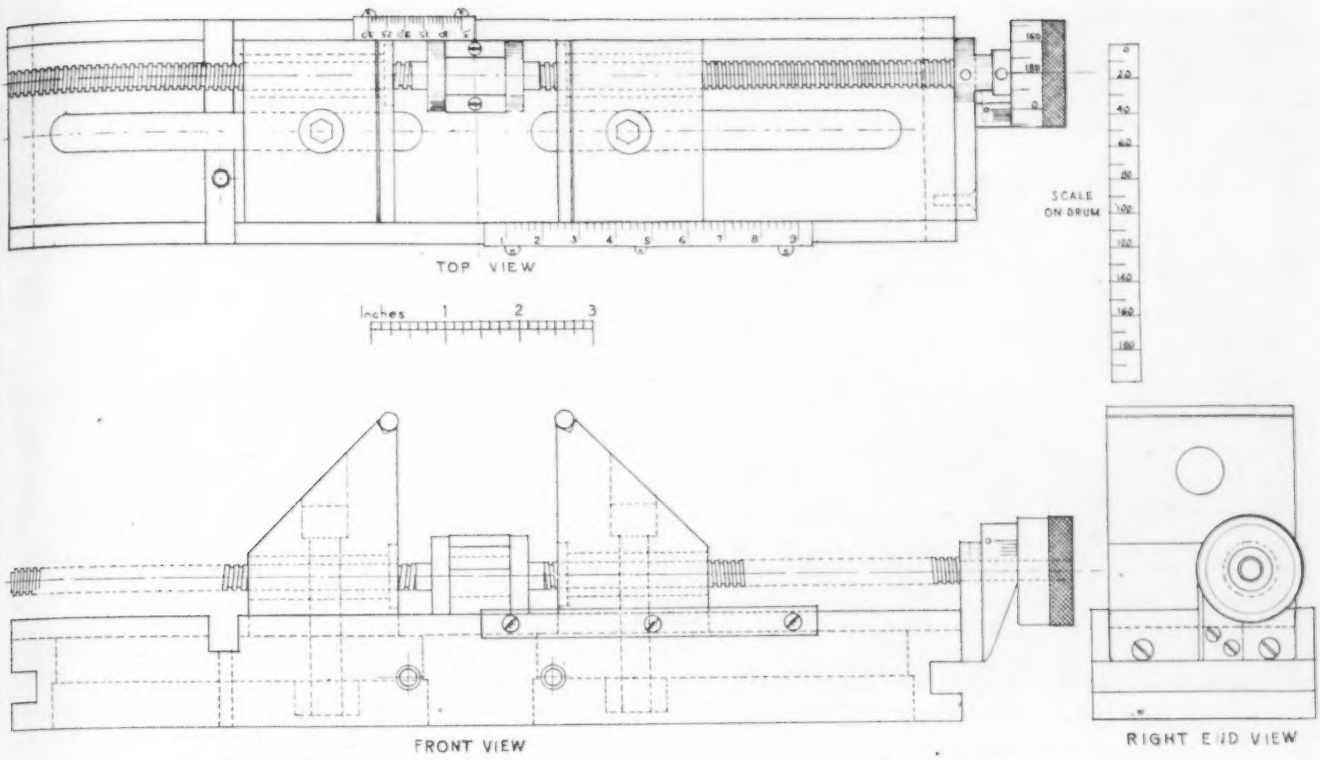

Fig. 1.—Assembly Drawing of Variable-Span Flexure Test Jig with $\frac{1}{8}$-in. Radius Supports.

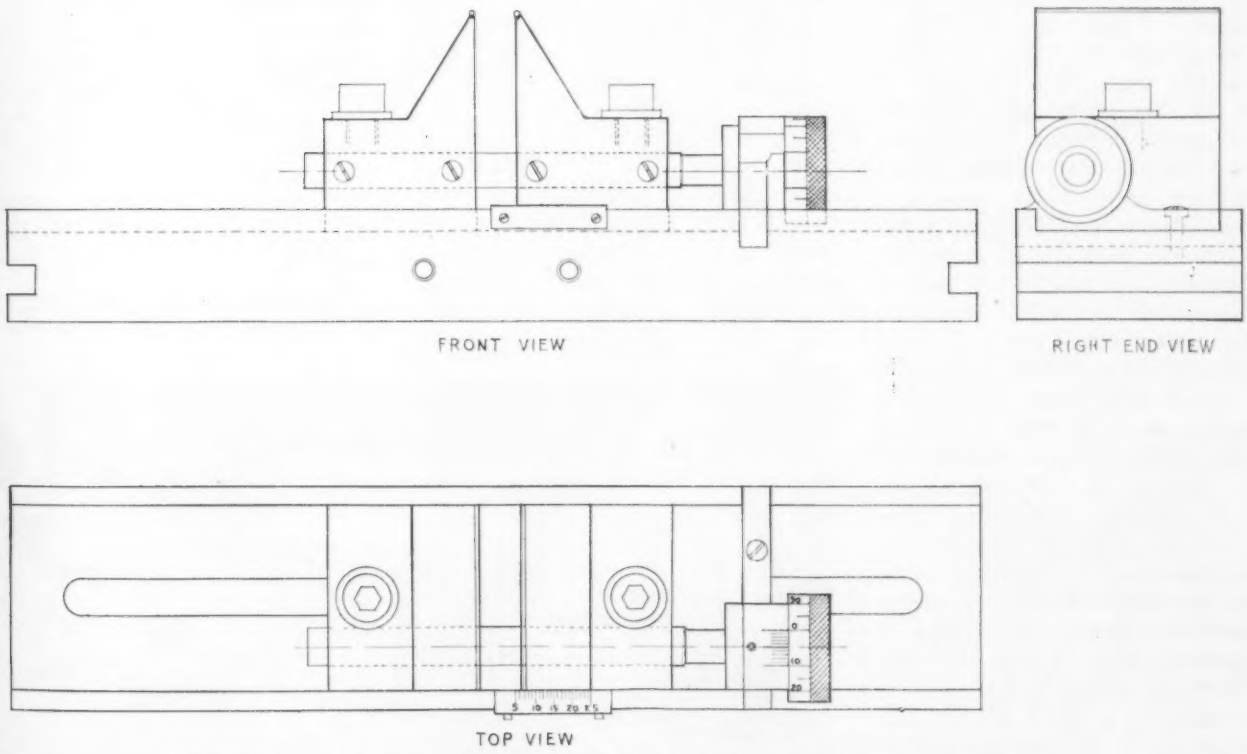

Fig. 2.—Assembly Drawing of Variable-Span Flexure Test Jig with $\frac{1}{32}$-in. Radius Supports.

blocks are shown in Figs. 1 and 2. Figure 3 shows the flexure jig with the $\frac{1}{8}$-in. supports in place in a universal hydraulic testing machine of the fluid-support, Bourdon-tube type.

The details of the flexure apparatus are as follows: A pressure piece A is attached to the sensitive crosshead of the testing machine. The support blocks B of the flexure jig are moved in a channel in the base C by turning the drum D on the micrometer-screw E. The micrometer-screw has the right-hand and left-hand thread arrangement mentioned above. At the desired span the support blocks are

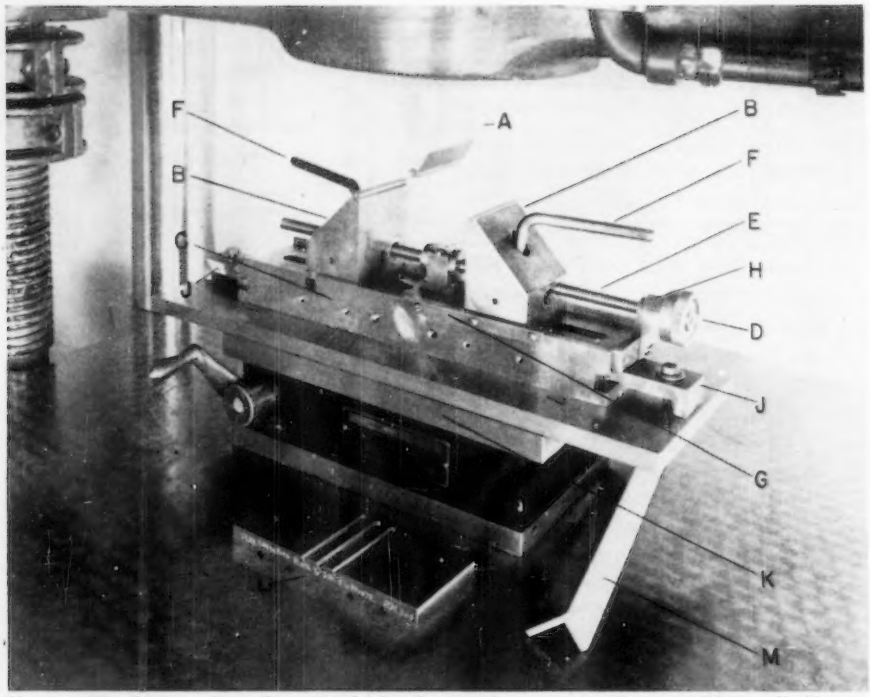

Fig. 3.—The Flexure Test Jig, with ⅛-in. Radius Supports, in Place in a Hydraulic Testing Machine.

locked in place by hexagon socket-head cap screws tightened by wrenches *F*. The span is indicated to the nearest 0.1 in. by the scale *G* on the base with the vertical edge of the right-hand support block as an indicator. The drum *D* and the fiduciary bracket *H* are graduated so that the span can be set directly to 0.001 and 0.002 in. with the $\frac{1}{32}$- and ⅛-in. supports, respectively. The flexure jig is clamped with toeplates *J* to a steel plate permanently fastened to a permanent-magnet type chuck *K*. The chuck is inverted so that the magnetic face will hold the chuck firmly to the testing machine platen.

In testing, the flexure jig is initially centered and aligned relative to the pressure piece in the following way. The alignment plate *L* having parallel V-grooves is used to locate the flexure jig relative to the pressure piece *A* after the span has been set appropriately. This is done with the contact edge of the pressure piece in the central V-groove in *L* under a light load. The flexure jig is clamped to the magnetic chuck and the latter is energized. The flexure jig is now self-centering. Subsequent changes in the span merely require loosening the cap screws, setting the micrometer screw, and tightening the cap screws again. To eliminate the effect of play, the span is always set by rotating the micrometer screw toward smaller readings. The specimen is centered and aligned with the angle-brass bar *M*.

The flexure jig base and support blocks are made of hot-rolled steel, the calibrated screw of drill rod. The contact edges of the pressure piece and supports are hardened drill rods soldered into place. The bushings in the support blocks and the thrust bearing are of bronze.[6]

A calibration was made of the flexure apparatus to determine the accuracy of the indicated span. The distance between the axes of the drill rods in the support blocks was the quantity actually measured in this calibration. With the ⅛-in. radius supports, the deviation from nominal span was 0.003 in. or less; the repeatability of position was poorer than expected with occasional variations as much as 0.006 in. For the $\frac{1}{32}$-in. radius supports the indicated span was 0.000 to 0.002 in. greater than the actual value; the positions of the supports repeated to better than 0.0005 in.

Deflection Apparatus:

Inasmuch as a suitable gage for recording the deflection of the specimen was not available when the flexure jig was built, an extensometer was adapted for this purpose. The deflection apparatus is shown attached to the flexure jig in Fig. 4.

The deflection of the specimen at the center of the span relative to the supports is indicated by an equal-arm lever actuating a Southwark-Peters plastics extensometer, Type PS-6 or PS-7. The extensometer is attached to two Dural brackets, one on the lever, the other attached to the base of the lever support. The Dural brackets have grooves to locate the knife edges of the extensometer. Load-

[6] Drawings of the flexure apparatus may be obtained from the Organic Plastics Section, National Bureau of Standards, Washington 25, D. C.

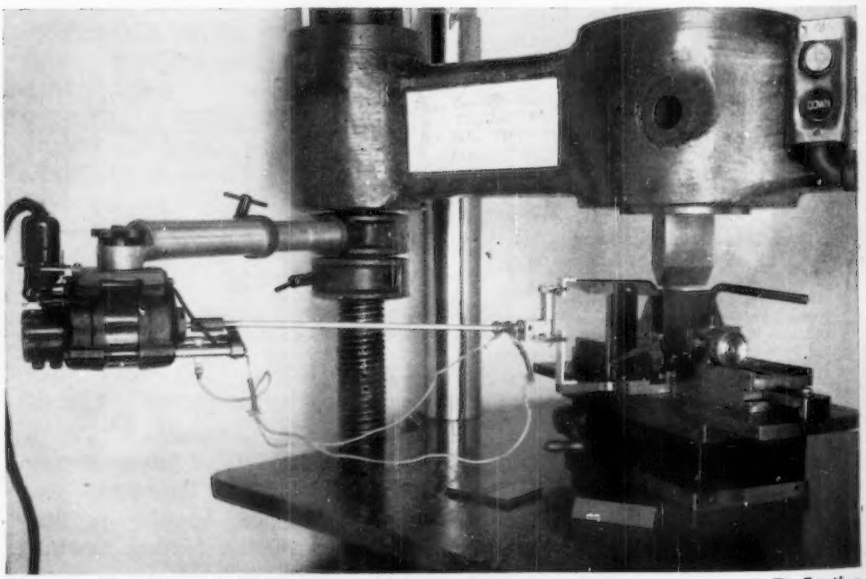

Fig. 4.—The Flexure Test Apparatus with Recording Extensometer and Deflection Lever Attached; the Supports Are $\frac{1}{32}$-in. Radius.

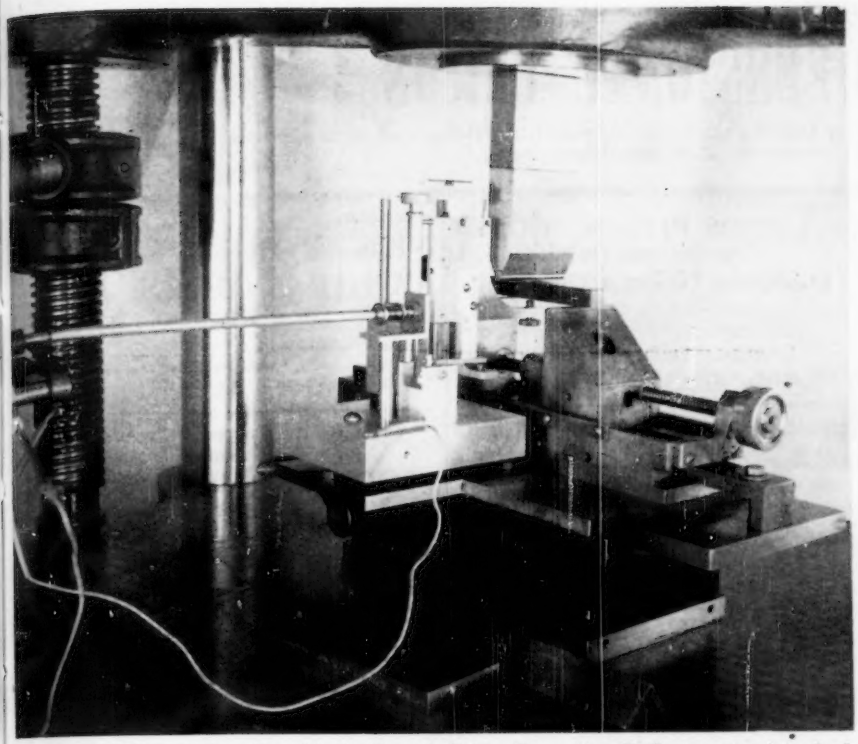

Fig. 5.—The Flexure Test Jig with Southwark-Peters Recording Deflectometer Attached.

deflection graphs are obtained with this extensometer coupled to a Templin type recorder on the testing machine. The high magnification gage, model PS-6, has a range of 0.23 in. and the low magnification gage, model PS-7, a range of 1 in.

The deflection attachment was calibrated with a screw micrometer depth gage. The combination of recording extensometer and lever is accurate to about 5 per cent in the measurement of deflections over 0.01 in. with the PS-6 gage and to about 3 per cent for deflections over 0.1 in. with the PS-7 gage. The percentage error diminishes as the deflection increases.

Recently a recording deflectometer, for use with a Templin type recorder to obtain load-deflection graphs, has become available. It is possible to use the deflectometer with the variable-span flexure jig (Fig. 5) by increasing the length of the pressure piece and using a large steel plate for a platform. The manipulation with the deflectometer is almost the same as with the deflection lever arrangement. The deflectometer should indicate deflection more accurately than the deflection lever apparatus.

For tests at an elevated temperature or in a moisture-saturated atmosphere, the deflection lever arrangement, which permits the recording gage to be outside the test atmosphere, has an advantage over the deflectometer.

Discussion

The flexure equipment described has been used to a considerable extent in this laboratory and results obtained with it are included in several publications[4] (1, 2, 3). The use of this equipment in a test enclosure operated at temperatures of −70 and 200 F. is described briefly in N.A.C.A. Technical Note 1054 (2).

The authors realize that the apparatus is capable of considerable improvement and offer this article with the hope that other workers concerned with testing plastics may be able to use some of the features in this first model of a variable span flexure jig with micrometer screw.

Acknowledgment:

The development of this apparatus was suggested by P. S. Turner of this laboratory. His work on the effect of span-depth ratio on the flexural strength of plastics led him to recommend that apparatus of the type described be built.

The use of the magnetic chuck was suggested by H. J. Kaiser of this Bureau.

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